ABSTRACT

Emilie Savage-Smith, with a chapter by Andrea P.A. Belloli. Islamicate Celestial Globes: Their History, Construction, and Use. *Smithsonian Studies in History and Technology*, no. 46, 354 pages, 87 figures, 7 tables, indices, 1985.—Islamicate celestial globes made as early as the eleventh century are found in museums and private collections today. There are also references in classical Greek and Roman literature to earlier globes that are no longer extant. These globes are of interest to the history of astronomy, of art, and of technology.

The globe presently in the National Museum of American History of the Smithsonian Institution, which is a fine example of a seventeenth-century Mughal Indian globe, was selected for detailed analysis and serves as the focus for this monograph. The first part of the study compares this particular globe with other known Islamicate globes and places the development of such globes within the historical perspective of the earlier Greco-Roman world from which it drew many of its traditions. An historical survey is given of all references and artifacts from the Greco-Roman and Islamic world that can have bearing on our knowledge of the design, construction, and use of such globes. The nature and general characteristics of three basic types of Islamicate celestial globes, and their probable uses as well as methods of construction, are the subjects of the second chapter of the study. Photographs of selected Islamicate globes from the thirteenth to the nineteenth centuries, as well as line drawings based on written descriptions, accompany the historical and analytical discussion.

The fourth chapter on iconography analyses the constellation figures on the Smithsonian globe from the perspective of an art historian. This chapter was contributed by Andrea P.A. Belloli.

The second major part of the study presents a discussion of the star names engraved on the Mughal globe, tracing the origins of the terms in Greek mythology or early Bedouin constellation outlines. The discussion of each constellation is accompanied by a photograph of the constellation as depicted on the Smithsonian globe. An account of lunar mansions is included as background to early Bedouin asterisms, which greatly affected later Islamicate star names and eventually "modern" western star names.

The sixth section presents an extensive descriptive catalogue of the 126 Islamicate celestial globes known to scholars prior to 1982. The references in the other sections to particular globes are keyed to the entry numbers in this catalog. Following the catalog are tables comparing the features of the globes and transcriptions of the signature inscriptions. Six entries (Nos. 127–132) were added to the catalog while the study was in press.

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Contents

FOREWORD

This comprehensive study of Islamicate globes was initiated in the most casual manner one spring day more than ten years ago in my office as Deputy Director of the National Museum of History and Technology (now the National Museum of American History).

The Museum had just acquired a most interesting celestial globe but there was no one on hand who could read its inscriptions. At the time there was no one on the professional staff with a knowledge of the Arabic language. The lack was soon remedied, however, with the discovery that Mrs. Emilie Savage-Smith, a Smithsonian post-doctoral Fellow working in the Division of Medical Sciences, was familiar with the language. When called upon, she readily provided the information needed.

But the story did not end there. Mrs. Savage-Smith became intrigued with the globe, and her preliminary research revealed that this was a category of instruments that had been neglected by scholars. Realizing that a study of Islamicate globes presented an unusual opportunity to make a contribution to the literature, she undertook a more detailed examination of the example in the Museum, and then began a search for others with which to compare it. Little did she realize at the time that she was launched on a project that was to preoccupy her for the next decade and would take her to far places.

As a first step, arrangements were made with the Smithsonian's Conservation-Analytical Laboratory to make a thorough technical analysis of the Museum's globe to determine the techniques of construction and nature of the metal. The results of this analysis are included in Chapters 2 and 3 of this paper.

Meanwhile the author sought out other globes in American public and private collections, and then extended her search to repositories in England, France, Egypt, and other countries. As each globe was examined, photographed, and documented, the information collected was made part of a case study by means of which it became possible not only to establish the dates and places of origin, but also to relate Islamicate globes in historical perspective with the production of scientific instruments derived from the Greco-Roman tradition in the Islamic world.

The project became a rewarding adventure in historical detective work as the author continued to locate and document the 126 globes that are cataloged in this work, consulting with authorities on Islamicate astronomy and instrumentation in the United States and abroad. Almost a full ten years passed before the search was completed and the findings brought together for publication in this paper.

This monograph may not be the last to be written on the subject, but as

the first it breaks new ground. Not only will it supplement studies of science in Islam, but will prove to be an invaluable resource for historians of science and of scientific instrumentation in general.

Silvio A. Bedini
Keeper of the Rare Books
Smithsonian Institution

PREFACE

This historical survey of the design and construction of Islamicate celestial globes and their Greco-Roman antecedents pays particular attention to the products of seventeenth-century Mughal India. The globe that serves as the focus of the study is one of the finest examples of precision workmanship among all the 126 extant Islamicate celestial globes and is, moreover, a seamless hollow cast globe. The fact that many Islamicate globes are hollow seamless metal spheres and that this technique was a speciality of a particular workshop of instrument makers in Lahore seems not to have been noticed until this study was begun 12 years ago.

In order to properly assess the products of the Lahore workshop, as much information as possible was needed concerning other Islamicate celestial globes. This author's effort to assemble this information resulted in the catalog of all Islamicate celestial globes known as of the spring of 1982 to be extant. The many references to celestial globes throughout this study are keyed to the entry numbers in this catalog, which comprises chapter 6 of this study. It is hoped that with this publication even more celestial globes now in small museums and private collections will come to light and be made available for study by scholars so that a fuller picture will emerge of the development of the design and construction techniques. While the study was in press six entries (Nos. 127–132) were added to the catalog; these globes do not figure, however, in the general analyses and comparisons made elsewhere in the book.

In order to appropriately designate the non-religious aspects of the complex of cultural traditions in a society historically associated with the religion of Islam, some term other than "Islamic" is needed. I have chosen to use Islamicate, for whereas the word "Islamic" refers to subjects directly related to, growing out of, or affected by the religion of Islam, Islamicate can be used to refer to objects or cultural features that are not related directly to the religion but are often based on traditions taken over from other cultures and nurtured and developed by Muslims and non-Muslims alike. When speaking of science and technology in the Islamic world, Islamicate is a particularly appropriate term, as this topic of celestial globes illustrates. These globes represent a tradition of instrument design inherited from the Hellenistic, Roman, and Byzantine worlds, and except for minor points of design and considerable progress in construction techniques, that tradition, unaffected by religious belief or dogma, remained essentially unchanged through the end of the nineteenth century. Among the makers of the instruments and the authors of treatises on celestial globes there were Christians, Muslims, and Hindus, and the languages used in their works included Arabic, Persian, Indo-Persian, Ottoman Turkish, and even Sanskrit. Yet all are representative of a secular culture shared by an enormous area from Spain to the Indus that

was marked by the domination, at one time or another, of the political-religious structure of Islam, in what has been loosely termed the Islamic world, or Islamdom. All the extant globes, whether from Spain or India, whether made by Muslim or non-Muslim, whether inscribed in Arabic, Persian, or Sanskrit, reflect an aspect of the culture of Islamdom.

The examination of the Mughal celestial globe's design and construction and that of its historical antecedents came about after the National Museum of American History (then the National Museum of History and Technology) acquired (at first on loan) the anonymous and undated globe in 1972. That globe became the primary object of this investigation. My study and analysis of the globe was instigated and encouraged by Silvio A. Bedini, presently Keeper of the Rare Books and former Deputy Director of the National Museum of History and Technology; Dr. Uta C. Merzbach, Curator of the Division of Mathematics; and Deborah J. Warner, Associate Curator of the Division of Physical Sciences, where the globe is presently located. The laboratory analysis of the globe was carried out by Maurice Salmon, formerly of the Conservation and Analytical Laboratory of the National Museum of American History. For reasons completely beyond the control of the present author, the analysis has not been published. It is hoped that it will be subsequently published in detail and interpreted by someone more knowledgeable then myself in such matters.

I was most fortunate in being able to have an art historian, Andrea P.A. Belloli of the Los Angeles County Art Museum, contribute to this study a chapter on the iconography of the Smithsonian globe. Using art historical evidence she analyses the products of this Mughal workshop and attributes the globe to one particular designer and scientific instrument maker within this large workshop—arriving at the same conclusion to which I was forced independently by the examination of the linguistic and technical features of the globe. I wish to express my special thanks to her for undertaking this chapter and so rigorously meeting all appointed deadlines. She bears no responsibility, however, for whatever errors or misinterpretations are to be found elsewhere in this study.

The nature of the study has necessarily involved a large number of people who have given assistance in various ways. The author is particularly indebted to the enormous assistance given through conversations by Francis R. Maddison, Curator of the History of Science Museum, University of Oxford, who made many valuable suggestions based on his extensive knowledge of Islamicate scientific instruments. In addition, both he and Alain Brieux of Paris most generously placed at my disposal all the files for their comprehensive repertoire of signed or dated Islamicate scientific instruments, which they are preparing jointly.

Among the persons who gave liberally of their time to supply needed information and answer queries I would particularly like to mention Anthony J. Turner of Le Mesnil-le-Roi, France, and Roderick and Marjorie Webster, Curators of the Adler Planetarium, Chicago, as well as acknowledge the kind assistance of R.G.W. Anderson, formerly Assistant Keeper of the Department of Technology, the Royal Scottish Museum, Edinburgh, and now with the

Science Museum, London; Madame Marthe Bernus-Taylor, Conservateur à la Section Islamique, Musée du Louvre; D.J. Bryden, formerly of the Whipple Museum of the History of Science, University of Cambridge; Professor D.J. de Solla Price of Yale University whose untimely death occurred just before publication; Dr. Muammer Dizer, Director of the History of Science Museum, Kandilli Observatory, Istanbul; Michael Robinson, Assistant Keeper, Department of Art, Ulster Museum, Belfast; J.S. Simons, Technician, Museum of the History of Science, University of Oxford; Professor Cyril Stanley Smith, Massachusetts Institute of Technology; and Christopher Terrell, Curator of Hydrography of the National Maritime Museum, London. Helpful suggestions regarding one or more of the signature inscriptions were given by Dr. Ismail K. Poonawala, Department of Near Eastern Languages, UCLA, and James R. Reid and Mehri Reid of the Von Grunebaum Center for Near Eastern Studies, UCLA, and some brief linguistic enquiries were answered by Julian Baldick of Wolfson College, University of Oxford; Beatrice F. Manz and Menuchechr Mohandessi of Harvard University; Serge Obolenski of the U.S. Foreign Service; and Mary Chase Smith of the University of North Carolina, Chapel Hill. The author also wishes to thank Judy Erickson von Gunten, who translated Spanish texts for my use and drew sketches of constellation figures from several globes.

Many museums and private collectors assisted by graciously allowing me to examine the globes or by supplying photographs: Madame Marthe Bernus-Taylor, Conservateur à la Section Islamique, Musée du Louvre; Alain Brieux of Paris; Michael V. Butler, Curator of Physics, Cranbrook Institute of Science, Bloomfield Hills, Michigan; Marcel Destombes of Paris, who kindly let me examine his very important personal collection of Islamicate globes; Jan Dolman, Assistant Curator, the Time Museum, Rockford, Illinois; Wafiyya Ezzi (deceased), former director, and Abu El-Raʾūf Ali Yousuf current director, the Museum of Islamic Art, Cairo; Mr. and Mrs. David H.H. Felix of Philadelphia; Kenneth A. Lohf, Librarian for Rare Books and Manuscripts, Butler Library, Columbia University, New York; A.E.R. North, Department of Metalwork, and A.G. Mitchell, Indian Section, of the Victoria and Albert Museum, London; Miss Dorothy E. Miner, Librarian, Walters Art Gallery, Baltimore; R.H. Pinder-Wilson, former Deputy Director of the Department of Oriental Antiquities, British Museum, London; D. Morgan Rees (deceased), former Keeper of the Department of Industry, the National Museum of Wales (now the Welsh Industrial and Maritime Museum, Amgueddfa Diwydiant a Môr Cymru), Cardiff; A.N. Stimson, Curator of Navigation, and Miss Drucilla Bates, of the National Maritime Museum, London (Greenwich); A.C. Thompson, Keeper, and R.G.W. Anderson, Assistant Keeper, of the Department of Technology, the Royal Scottish Museum, Edinburgh; The Reverend F.J. Turner, S.J., Librarian, Stonyhurst College, Lancashire, England; and Antony Vincent, Department of Astronomy and Geophysics, the Science Museum, London.

In addition to those mentioned earlier, others at the Smithsonian have given advice and assistance, including Esin Atil of the Freer Gallery of Art; William T. Chase of the Conservation Laboratory of the Freer Gallery of

Art; George Norton, museum specialist of the Division of Physical Sciences of the National Museum of American History; and Robert Organ, Chief of the Conservation and Analytical Laboratory of the National Museum of American History. I also wish to express my appreciation to Rebecca Curzon, publications coordinator of the National Museum of American History, who consistently showed interest and courtesy in handling the publication of this study; Alice Gergely of the National Museum of American History who patiently typed the tables; and Theresa J. Slowik, technical publications editor of the Smithsonian Institution Press, who meticulously groomed and prepared the manuscript for press.

There are, of course, many scholars whose previous writings were of fundamental usefulness to this study; among them I would particularly mention P. Kunitzsch, whose studies of Arabic star nomenclature must be extensively employed in any discussion of the topic. Furthermore, any examination of Islamicate celestial globes is necessarily indebted to the studies of some of the early globes by Marcel Destombes, who at the time of his recent death was nearing completion of an analysis of Islamicate celestial globes prior to AD 1500, giving special attention to the star names.

In addition to the photographs of the Smithsonian globe prepared by the photographic laboratory of the National Museum of American History, there are other photographs used in this publication, a number of which were most generously supplied by Alain Brieux of Paris, while the Musée du Louvre, the Whipple Museum of the History of Science, the National Maritime Museum (London-Greenwich), the Royal Scottish Museum, the Time Museum of Rockford, Illinois, and Columbia University also furnished photographs of items in their collections. Three photographs of unknown origin are drawn from the files of the History of Science Museum, Oxford, and the Whipple Museum of the History of Science, Cambridge. The author wishes to thank the Adler Planetarium, Chicago; Alain Brieux of Paris; the British Museum; Columbia University, New York; the Cranbrook Institute of Science, Michigan; Musée du Louvre; the Museum of the History of Science, Oxford; the National Maritime Museum, London (Greenwich); the Royal Scottish Museum; Stonyhurst College, Lancashire, England; the Time Museum, Illinois; the Victoria and Albert Museum; the Welsh Industrial and Maritime Museum; and the Whipple Museum of the History of Science, for granting permission to publish photographs.

To the constant support and inspiration of M.B.S., friend, lover, scholar, crank, this study is dedicated.

Emilie Savage-Smith

Islamicate Celestial Globes: Their History, Construction, and Use

Emilie Savage-Smith

Introduction

The globe that is the particular focus of the study is an anonymous and undated hollow metal seamless sphere. It shows about 1022 inlaid silver stars and has 48 constellation figures and numerous star names engraved on its surface. The attribution of this globe to a particular maker was arrived at independently by an historian of science and an art historian (Andrea P.A. Belloli). Thus, the conclusions given here may serve as a case study of how scholars having different viewpoints and employing different methodologies can approach the same body of evidence and arrive at the same conclusions without knowledge of one another's findings. Both scholars, one using art historical evidence and the other linguistic and technological arguments, agreed upon a definite attribution to one particular designer and scientific instrument maker within a large workshop. The globe is a fine example of the Mughal Indian celestial globes of the seventeenth century, a period that has received relatively little attention and is thoroughly within the tradition of medieval Islamicate scientific thought. This particular globe is, moreover, one of the finest examples of precision instrument making among all the extant Islamicate celestial globes. This globe is also a good example of constructing a globe by casting a hollow seamless sphere using the *cire perdue* (lost wax) method—an intricate process in which a particular family workshop of astrolabe makers in Lahore excelled during the sixteenth and seventeenth centuries. There is some evidence that the technique might have developed outside of northwestern India and as early as the thirteenth century, though unfortunately all the evidence for this theory rests on globes whose authenticity is questionable. The seamless nature of certain Islamicate metal globes was not recognized until this study was undertaken. These Islamicate celestial globes are the only known examples of hollow cast seamless spheres.

Note on Transliteration and Dates.—With the Arabic I have tried to follow for the most part the orthography rather than the pronunciation, emphasizing the element of reversibility in the transliteration. I have employed basically the Library of Congress System with a few of the variations given by Hodgson (9–10). A macron rather than a circumflex has been used to indicate long vowels. The Arabic article is never assimilated to the following noun. The double *yāʾ* after *kasrah* is written as *īy* rather than *iyy*, and the *hamzah* at the start of a word is omitted. The final *a* written in Arabic with a *yāʾ* (*alif maqṣūrah*) is written as *-à*. The feminine ending of a noun or adjective is indicated by a *tāʾ marbūṭah*, which is a combination of an *h* with the diacritical marks of a *t* and pronounced sometimes as an *h* and sometimes as a *t* and sometimes

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not at all. In this study it is usually written as an *h*, except when the word occurs before a noun in the genitive or construct state (*iḍāfah*), in which case it is written as a *t*. For example, by itself the word for "work" or "opus" would be *ṣanʿah*, but in the statement "the work of Yūnus ibn al-Ḥusayn al-Aṣṭurlābī" it would be written as *ṣanʿat Yūnus ibn al-Ḥusayn al-Aṣṭurlābī*.

In the case of transliterating Persian and Indo-Persian, I have tended to transliterate the words with the same alphabet used for the Arabic with the addition of four letters *p, ch, zh,* and *g*. In this procedure I deviate from the system employed by the Library of Congress. Thus I write Ḍiyāʾ al-Dīn instead of Ziyāʾ ad-Dīn. It is with some regret that I do this, for I recognize that Persian is a separate language despite the fact that it is written with the Arabic alphabet. The choice was made, however, because I am a better Arabist than Persianist and because Arabic is the basic language of all the globes, except for the two with Sanskrit inscriptions, with the Persian and Indo-Persian (and in one case Ottoman Turkish) occurring, except for a few minor words, only in the signature inscriptions. The reader will find in Chapter 8 all the signature inscriptions on the globes written in Arabic and Persian alphabets.

Throughout the study, dates given in the Islamic era, that of the Hijrah, are designated by H, while those of the common Christian or Gregorian calendar are indicated by AD (anno Domini). Whenever a reference occurs to a century with no designation of calendar, the common Christian era is intended. Because this study is written in a European language, I have tended to give only the equivalent Christian dates when greater specificity seemed unnecessary. When referring to the date of a particular product, I place the Hijrah date first followed by the Christian date. Thus in the historical sections a date of a product will have the form 622 H/AD 1225–1226. The actual date on Islamicate scientific instruments and treatises is not given in the Christian era (with one exception on a single globe), but in that of the Hijrah or some other Eastern calendar (see Table 5 in Chapter 7 for all the calendrical eras used on Islamicate globes).

NOTE ON REFERENCES AND BIBLIOGRAPHY.—The references in this book use a shortened form that has been devised to overcome the difficulties of dealing with classical texts and scientific works within the same system. Each work listed in the Bibliography is alphabetized under its shortened form—usually the author's or editor's name, and either an abbreviated title or the year of publication.

These short forms are used in the notes to Chapters 1–5 and in the Citations sections in the Catalog. In the discussion of the Constellations in Chapter 5, where a limited number of treatises are used repeatedly, the short forms are used in the text itself and refer the reader directly to the Bibliography.

For classical works, the traditional system of book and line numbers has been used; e.g., Homer *Il.*, II,15 refers to Book II line 15 of Homer's *Iliad*. For Aratus's poem, *Phaenomena*, line numbers are given. Thus these references can be found easily in any edition. Where a particular translation has been quoted, the translator is specified and page numbers are given. For more contemporary sources the short form of the reference is followed by volume and page numbers as necessary; e.g., *EI* [2], 4:387 refers to page 387 in Volume 4 of the second edition of the *Encyclopaedia of Islam*.

Historical Overview

1. A History of Celestial Globes in the Greco-Roman and Islamic Worlds

From Zeus let us begin; him do we mortals never leave unnamed . . . for himself it was who set the signs in heaven, and marked out the constellations, and for the year devised what stars chiefly should give to men right signs of the seasons, to the end that all things might grow unfailingly.

Aratus
Phaenomena

Patterns of stars and their collective movement across the sky have been of interest to people from the earliest historical periods. The stars have been commonly, though perhaps not universally,[1] perceived as though attached to the inside of a hollow sphere enclosing and rotating about the earth. It is therefore reasonable that the earliest attempts to represent in a model the arrangement and movement of the stars were by means of a celestial globe. The earth, which was known to be spherical from early classical antiquity, was imagined at the center of the globe, while the stars were placed on the globe so that the resulting model presented the stars as seen by an observer outside the sphere of fixed stars. Consequently, the relative positions of the stars on a celestial globe are the reverse, east to west, of their appearance when viewed from the surface of the earth.

In antiquity, the idea of constructing a physical model to represent certain celestial phenomena appears to have been peculiarly Greek, as was the attempt to represent the known world on a terrestrial globe, if we can accept as authentic the few references to terrestrial globes.[2] Tradition has it that Anaximander of Miletus (610–547 BC) made a map of the earth and sea and made a globe (σφαῖρα), possibly terrestrial.[3]

According to Cicero,[4] who reported the statements of the Roman astronomer Gaius Sulpicius Gallus of the second century BC, the first globe was constructed by Thales of Miletus (sixth century BC). The account continues:

Subsequently, Eudoxus of Cnidos [ca. 390–340 BC], Plato's pupil, as Gallus said, marked on the globe the stars that are fixed in the sky. Many years after Eudoxus, Aratus adopted from him the entire detailed arrangement of the globe and described it in verse, not displaying any knowledge of astronomy but showing considerable poetical skill.[5]

Eudoxus was an astronomer who appears to have had considerable influence on later Greek astronomers.[6] Unfortunately nothing remains today of his writing except some possible fragments. Whether or not Eudoxus actually used a celestial globe, he did compile a descriptive list of constellations, with their calendric risings and settings, which he prepared in two versions titled Ἔνοπτρα (mirrors) and Φαινόμενα (phenomena).

The latter version was no doubt the basis for the extraordinarily influential astronomical poem *Phaenomena* (Φαινόμενα) by Aratus of Soli in Cilicia (ca. 315–240 BC).[7] This poem was undertaken at the request of Antigonus Gonatas who, as ruler of Macedonia, formed around the court an active literary circle.[8] The *Phaenomena* surveys in very general terms with no precise indications of positions or distances the northern (including zodiacal) and southern constellations, the circles of the celestial sphere, and the risings and settings of the fixed stars, followed by a long section, subtitled διοσημίαι (omens from the sky), on indications of weather phenomena. Approximately 48 distinct asterisms are described, including the Pleiades, which are considered separately from Taurus because of their importance, and a constellation called ὕδωρ (water), which may be the group later considered by Ptolemy to be the external stars of the Southern Fish.[9] In addition to the Milky Way (γάλα) the circles of the celestial sphere consist of the northern and south-

ern tropic circles (the Tropic of Cancer and Tropic of Capricorn), the celestial equator (ἰσημερινὸς κύκλος, or equinoctial), and the ecliptic (κύκλος λοξός or oblique circle sometimes called ζωίδιος κύκλος or zodiacal circle). Sometimes Aratus speaks of the circle of the zodiac as being only the ecliptic circle, and at other times as a zone extending about 6° to either side. Certain asterisms are described as being always visible, lying within the circle of perpetual visibility (ὁ ἀεὶ φανερὸς κύκλος), which indicates a certain geographical latitude.

The most frequently suggested latitude is that of about 37° or 38°, approximately that of Athens;[10] however, R. Böker has prepared a detailed technical analysis of the celestial globe that Aratus (and Eudoxus before him) may have used while composing the *Phaenomena*. He concluded that the celestial globe had the human constellation figures portrayed from the back (as if facing in toward the globe) and was designed for a particular geographical latitude, which he estimated to be between 32°30′ (that of the ruins of Babylon south of Baghdād) and 33°40′ (that of Tyrus in Phoenicia is 33°18′ and Sidon 33°34′), with the star positions relative to the equinoxes corresponding to the beginning of the tenth century BC, plus or minus 30 to 40 years.[11]

This significant example of didactic Hellenistic poetry consisting of 1154 hexameters[12] achieved great popularity, prompting many commentaries (the names of 27 are known)[13] and later Latin translations. These include one by Cicero (fragments of this youthful work still survive); another from Germanicus Caesar (born 15 BC), who was adopted by his uncle Tiberius and stood in direct line of succession; and another by Avienus, proconsul of Africa in AD 366. *Aratea* is the name given to the Latin versions of Aratus's *Phaenomena*, and they cover a period of some four hundred years.[14] In the ninth century the poem was translated into Arabic.[15]

While it is quite likely that even before the time of Eudoxus other early poems had been written on constellations, such as that by Cleostratus of Tenedos,[16] none were as influential as Aratus's versification of Eudoxus's *Phaenomena*. An extant treatise on the mythologies associated with the constellations entitled Καταστερισμοί is questionably attributed to the geographer, mathematician, and literary critic Eratosthenes of Cyrene (ca. 275–194 BC).[17] Though he is known to have written a treatise by this title, the extant prose fragment is probably spurious. It describes 42 constellations with the stars numbered in each, but with no stellar coordinates. In the later Roman world this work was an important source concerning the various myths related in antiquity to the constellation forms.[18]

It is highly unlikely that either Aratus or his predecessor Eudoxus made any methodical astronomical observations. The poem by Aratus seems to be describing a celestial globe, though one is never specifically mentioned. If we can accept the testimony offered by Cicero and his sources and that of the seventh-century Byzantine writer Leontius, who speaks of the greater simplicity of Aratean globes (ἀρατεία σφαῖρα),[19] celestial globes were employed by Aratus and possibly Eudoxus; the precise nature of these globes is not known today. There is no evidence that the globes were mounted in meridian and horizon rings as was to be the classical form throughout the Christian and Islamic eras. The globe was probably a sphere representing a number of prominent stars and 42–48 constellation outlines drawn around groups of the stars. The globe would have had great circles representing the ecliptic and the celestial equator, with two circles parallel to the equator indicating the tropic circles and two additional equatorial parallel circles indicating, the area of the heavens that would always be visible (or invisible) at whatever location the maker of the globe lived. There is no mention of colures or meridians on these early globes, nor any indication that they were to be rotated around the equatorial poles within a horizon ring to illustrate the movement of the heavens, though the later writers Manilius of the first century AD and Leontius of the seventh century place similar globes within a horizon ring.

While the *Phaenomena* is a smoothly written, easily readable poetic introduction to the con-

stellations, it is, as Cicero implies, astronomically deficient. Criticisms were made of Aratus's (as well as Eudoxus's) positioning and descriptions of the constellations and stars by Hipparchus in his *Commentary on the Phaenomena of Eudoxus and Aratus* (Ἐξήγησις τῶν Ἀράτου καὶ Εὐδόξου φαινομένων).[20] This commentary is the only preserved work by this great early astronomer, who was born at Nicaea in Bithynia about 190 BC.[21] It has been frequently stated that Hipparchus's catalog of stars (which is not extant as an independent work, but is contained in part in his commentary on Aratus) was virtually repeated by Ptolemy three centuries later in his *Almagest*, with appropriate changes in longitude. It has been conclusively shown,[22] however, that the Hipparchan catalog must have been quite different. In the *Commentary on Aratus* Hipparchus is concerned with describing only those stars, based on the latitude of Rhodes, that rise and set, thus ignoring the northernmost constellations, which are always visible. He uses no single system of coordinates and most significantly no ecliptic coordinates, and he makes no attempt to classify the stars by magnitude. For these and other reasons, although Hipparchus was apparently carrying out observations and was concerned with accurate descriptions and positions, his catalog of stars was certainly not repeated by Ptolemy, whose later catalog was fundamentally different. The number of stars, as well as the number of distinct constellations, in Hipparchus's catalog is ambiguous, but it seems there were between 45 and 47 constellations with no more than 850 stars.[23]

Hipparchus can also be credited with the discovery of the precession of the equinoxes, the slow movement of the equinoxes against the background of the fixed stars, which he assumed was at least 1° per hundred years.[24] It has long been assumed[25] that early astronomers, even before Hipparchus, commonly used celestial globes. Although there is no concrete evidence, such usage must be inferred from statements such as those found in Aratus's poem. It is probable that the type of celestial globe used by Hipparchus,[26] if indeed he used one, was a simple sphere not mounted in rings, designed only to display the relative positions of the stars and to indicate areas never visible and always visible at his location.

There seems also to have been an interest in terrestrial globes in the second century BC, if we are to believe the statement of the geographer Strabo, writing a century later, who says[27] a terrestrial globe was constructed by the Homeric scholar Crates of Mallos[28] about 170 BC. Strabo himself goes on to say that a terrestrial globe should be no less than 10 feet (δέκα ποδῶν) in diameter and that if the maker is unable to construct one of such a size he should instead draw a map on a plane surface seven feet across. Elsewhere in his *Geography* Strabo says that the "earth as a whole is sphere-shaped (σφαιροειδής), but not sphere-shaped as though from a turning-lathe (ἐκ τόρνου) but rather has some irregularities."[29] From this we may assume that it was customary to smooth the surface of wooden shapes by turning on a lathe. Such shapes probably included spheres, some of which may have been intended for use as globes.

In Cicero's tract *De republica*,[30] written in 51 BC, there are mentioned two celestial globes made in the third century BC by the great mathematician of Syracuse, Archimedes. Both globes had been taken from the city of Syracuse when Marcus Claudius Marcellus captured it in 212 BC during the Second Punic War. One globe had been placed in the Temple of Virtus in Rome and was more widely known than the other globe because it was more attractive. This particular globe was said to be solid (*sphaera solida*), having no hollow spaces, and according to the opinion of the astronomer Gaius Sulpicius Gallus, was of the early type of celestial globe, having the constellations and fixed stars on it. The second celestial globe made by Archimedes[31] had been taken home by the conqueror of Syracuse as his only share of the booty and was still in the family home when Gallus was consul (166 BC). This type of globe the astronomer Gallus called a newer class of globe:

> Gallus declared that the globe at Marcellus' house, which showed the motions of sun and moon and of those five wandering stars or planets as they are called [Mercury,

Venus, Mars, Jupiter, Saturn] could not be constructed in solid form. All the more remarkable, therefore, was Archimedes' discovery, since he had devised a method of construction whereby, extremely different though the movements of the planets are, the mere turning of the globe would keep them all in their unequal and different orbits. When Gallus rotated the globe, the moon really followed the sun on the bronze globe by the same number of revolutions as are the days it lags behind in the sky. Thus it happened that on the globe occurred a solar eclipse just like the real eclipse; and also that the moon passed into the tract of space covered by the earth's shadow when the sun [and the moon were on opposite sides of the earth]. (Text breaks off suddenly.)[32]

It is possible that what is being described here was a celestial globe placed at the center of a demonstrational armillary sphere, with rings representing the courses of the five planets, moon, and sun. It cannot be a celestial globe mounted in the two rings (a practice that seems to have been customary by the first century AD), for this globe of Archimedes had rings representing the movements of celestial bodies. It has also been interpreted as an early form of orrery, though why it would have been considered a variant of a celestial globe in that case is not clear. The description contrasts markedly with the solid sphere (which has no hollow spaces or rings, and was probably of the type used by Aratus and possibly Hipparchus).

A similar mechanical device for demonstrating the movement of the planets, sun, and moon against the background of the fixed stars was said by Cicero[33] to have been constructed by the philosopher Posidonius, with whom Cicero studied in Rhodes. Other references[34] to such contrivances can be found in the literature, including a possible one in Plato's *Timaeus*,[35] written in the fourth century BC, and a more detailed one in the major physiological treatise written in the second-century AD by the physician Galen.[36] These and other mentions of such demonstrational devices indicate that they were not uncommon in learned circles in Hellenistic and Roman times. Unfortunately, specific details of the arrangement and its precise relation to a celestial globe are unknown. It has been conjectured that even the simplest possible device that could regulate the movements of the planets, sun, and moon would require a system of gears meshing in parallel planes.[37] Several means have been suggested that Archimedes and others may have employed to turn the device, including a hydraulic mechanism[38] or a worm-wheel construction.[39] In any case, no artifact of such a device remains, though the tradition of a self-moving celestial sphere (without the planets, however) is discernable in a treatise written in Persia in the twelfth century, which describes a celestial globe half-sunk in a box; the globe is rotated once a day by an elaborate system of pulleys driven by a float on a sinking reservoir of sand.[40]

Writing in the first century BC, Geminus of Rhodes,[41] also a pupil of Posidonius, in his *Introduction to the Phaenomena* (Εἰσαγωγὴ εἰς τὰ φαινόμενα) mentioned two types of celestial globes, a "solid" variety (*στερεὰ σφαῖρα*) and a "ringed" style (*αἱ κρικωταὶ σφαῖραι*).[42] The latter type must refer to a demonstrational armillary sphere built about a celestial globe, but without a mechanism for indicating the movements of the moon, sun, and planets as designed by Archimedes. According to Geminus, the "ringed globe" was constructed with the "arctic" circle (*ἀρκτικός*) 36° from the north (celestial) pole;[43] the "arctic" circle was also 30° from the summer tropic circle (*θερινὸς τροπικός*), while the latter was 24° from the equator (*ἰσημερινός*), which in turn was 24° from the winter tropic circle (*χειμερινὸς τροπικός*).[44] The latter circle was then 30° from the "antarctic" circle (*ἀνταρκτικός*), which was 36° from the south pole (*νότος πόλος*).

Geminus goes on to say that both the "solid globe" and the "ringed globe" were constructed for only one geographical latitude—that is, 36° north, which is the latitude of Rhodes. The "arctic" and "antarctic" circles were defined as delimiting, respectively, the area of the heavens that was always visible and the area always invisible. Since the position of these two celestial circles would depend upon the location of the observer, the globe was valid for only one geographical latitude (in this case 36°), and a horizon ring surrounding a meridian ring that allows adjustment to different terrestrial latitudes was probably not employed. Indeed such circles are either

redundant or incorrect if a meridian-horizon ring assembly is used, depending on the setting of the rings. Presumably the "ringed" celestial globe as described by Geminus differed from the solid form by having the arctic and antarctic circles, tropics, and equator (and possible colures) indicated by rings surrounding the globe, on which were represented the ecliptic and some stars and constellations; the solid globe might have had the circles drawn directly on the surface of the globe itself.

The five parallel rings of a "ringed" globe were possibly held in place by one or two rings placed at right angles to them and attached to the equatorial poles of the globe (see Figure 1). If a third ring were then attached that touched the arctic and antarctic circles at one of the points where the circles intersect the outside perpendicular ring, this third ring would of course be an indicator of the horizon. There is no mention in the literature that this was ever done. It is also possible that the ecliptic was indicated by a ring (as well as on the sphere itself), in which case the two perpendicular rings to which the parallel ones were attached could serve as colures.

We have no information as to how the posi-

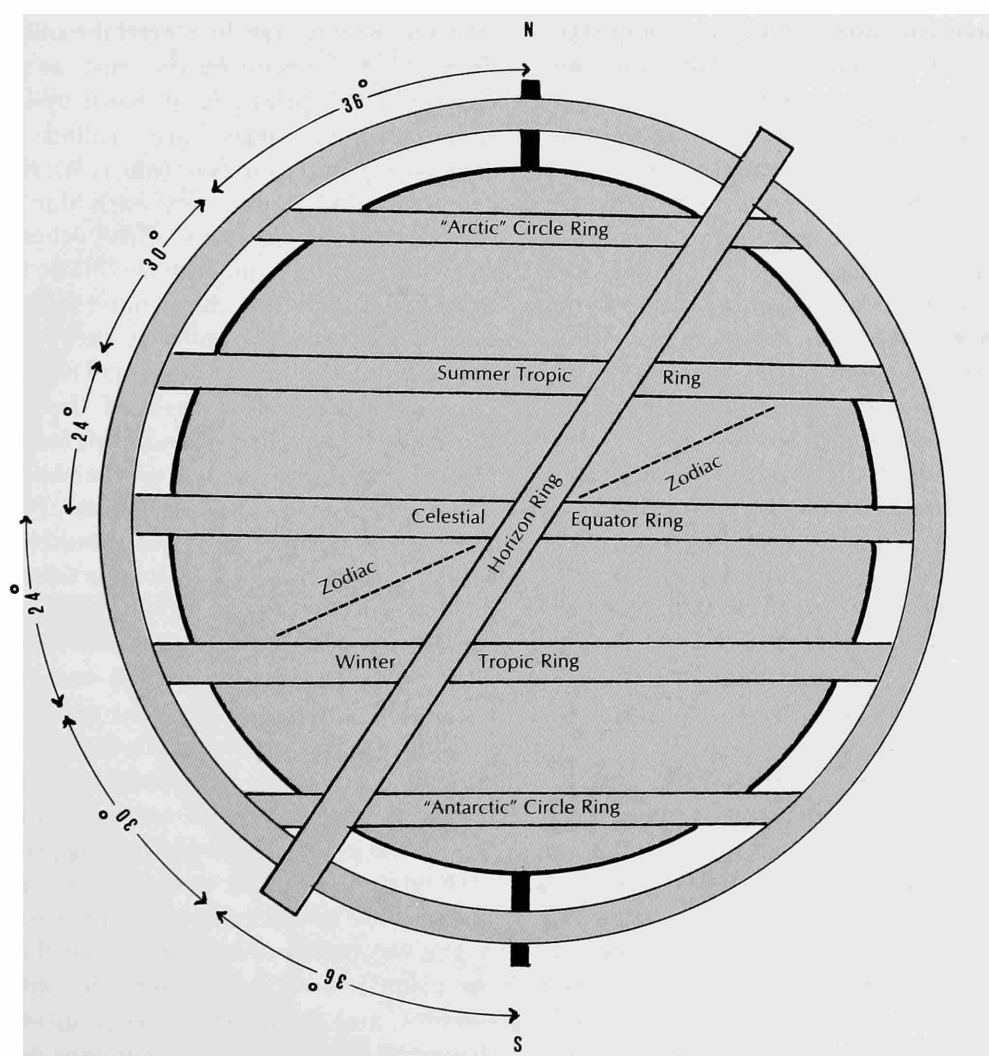



FIGURE 1.—Conjectured design of "ringed" celestial globe described by Geminus of Rhodes in the first century BC.

tions of the stars on a globe of this or earlier periods were determined. The use of coordinates seems highly unlikely. The constellations along the ecliptic were probably drawn first with others placed proportionately about, and then the stars marked within and outside the constellation outlines as was called for by the treatises discussing the constellations. From his inaccuracies and vagueness, one can conclude that whatever globes Aratus used were doubtless the results of such imprecise procedures.

The concepts of the "arctic" and "antarctic" circles being the "greatest always visible" circle and the "greatest always invisible" circle were no longer required on celestial globes shortly after the beginning of our era, for an horizon ring, enclosing an adjustable meridian ring, would indicate the always visible and always invisible areas of the firmament for any latitude desired, although the "greatest always invisible" circle remained important in the design of astrolabes.[45] Consequently on all Islamicate celestial globes there are no "arctic" and "antarctic" circles in the sense of circles marking areas of constant visibility or invisibility, but rather polar circles having the celestial poles at the center and the ecliptic pole on the circumference, thus having a radius equal to the obliquity of the ecliptic (see Figure 30). On Byzantine attempts to reconstruct the pre-Ptolemaic or Aratean celestial globes (such as that of Leontius), the "greatest always visible (invisible)" circle reappears. The very few preserved representations of Hellenistic and Roman celestial globes all represent the pre-Ptolemaic tradition by having such circles indicated on them.

There is no indication in these early descriptions of celestial globes that any of them were placed in a ring indicating the horizon line so as to demonstrate the movement and rising and setting of stars for the given geographical latitude. It appears that all celestial globes prior to our era were primarily designed to illustrate the relative positions of the major stars and constellations and to indicate those that were always visible at a certain latitude, as well as to show in general terms the course of the sun through the zodiac.

Ptolemy, the great astronomer of Alexandria (fl. AD 127–148), made two important contributions to the history of celestial globes: his star catalog, which formed the basis for all star catalogs used by globe makers in the Islamic world, and his detailed description of a particular type of celestial globe. In books VII and VIII of the *Almagest* (μεγίστη σύνταξις which, through the Arabic, became in Latin *Almagestum*)[46] Ptolemy presents a catalog of 1025 stars.[47] Each star is assigned a magnitude of one to six (some stars being described as greater or lesser than a given magnitude) and each star's relation to one of 48 constellation outlines is described by Ptolemy, who says he has slightly altered the outlines from those of his predecessors, just as they had changed the figures passed down by their predecessors. Five stars are called nebulous (νεφελοειδής) and nine faint (ἀμαυρός), rather than being assigned magnitudes; each star is given a specific position in terms of the ecliptic coordinates of longitude and latitude.[48] The longitudes were reckoned along the ecliptic from the position of the vernal equinox at the beginning of the reign of Antoninus Pius (AD 138).[49]

In book VIII, chapter 3 of the *Almagest*,[50] Ptolemy gives explicit instructions for the design of a celestial globe that will not become outdated by the precession of the equinoxes. Ptolemy begins by saying that the maker should take a solid sphere (στερεὰ σφαῖρα); no instructions are given as to how to construct the sphere or what material to use. He should then make the sphere a dark color (χρῶμα βαθύτερον) resembling the night sky. After selecting two antipodal points on the sphere, a great circle is to be made that is equally distant from both points; this circle is to represent the ecliptic. A second great circle is then to be passed through the two points; it will then be perpendicular to the first circle and pass through the two ecliptic poles. Beginning at one of the two points of intersection of these circles, the ecliptic is to be divided into 360 parts or degrees, and then into as many subdivisions of degrees as desired (such a comment presupposes a fairly large globe), and then the degrees are to be numbered. Next, two rings (κύκλοι) of strong and seasoned wood (ἐξ ὕλης εὐτόνου καὶ τεταμένης)

are to be made, one whose inner edge can just pass over the surface of the sphere, while the second ring has to be large enough to pass over the first ring. On one of the flat faces of each ring a semi-circular arc is drawn dividing the width of the face into two equal parts.[51] Then the semi-circular arc on each ring is graduated into 180° and labeled (beginning with 90° at each end of the arc and decreasing to zero at the center of the half-circle). The smaller of the two rings is pierced through at the two opposite points where the graduations begin and attached by two pins to the ecliptic poles of the globe (see Figure 2).

With the ring in place and able to rotate about the ecliptic poles, the stars can then be placed on the globe in their proper positions. To avoid the problem of the slow movement of the precession of the equinoxes outdating the globe, a constant and invariable point of reference must be taken, for which purpose Ptolemy selects the star Sirius ("in the mouth of the Great Dog," *α Canis Ma-*

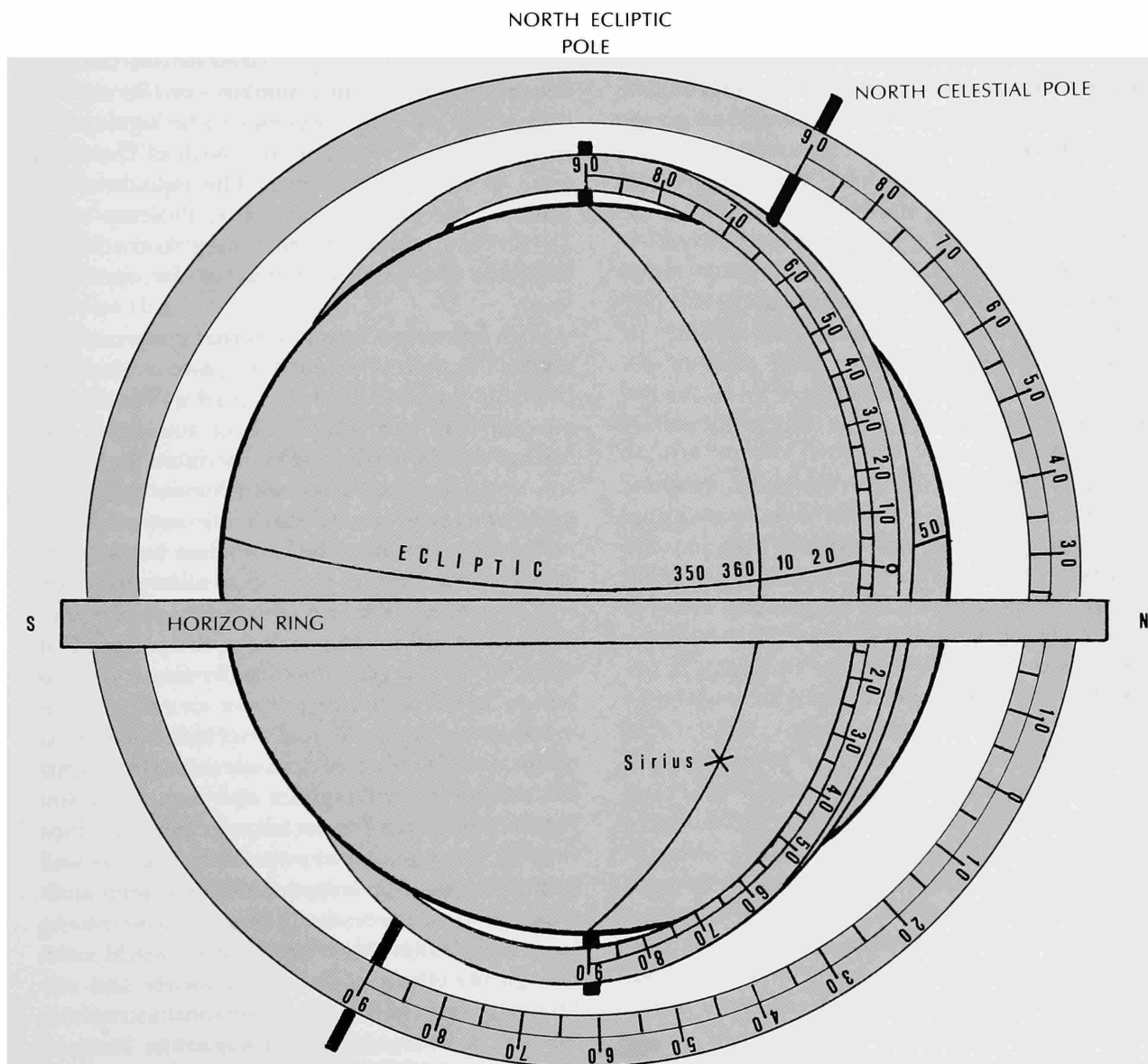



FIGURE 2.—Ptolemaic precession celestial globe.

joris). For greater accuracy in a later work, the *Handy Tables*, Ptolemy selects Regulus (*α Leonis*), which is closer to the ecliptic.[52] Sirius is then placed on the circle at right angles to the ecliptic, thereby assigning to Sirius a celestial longitude of 0°. Then the latitudinal position of Sirius on this great circle is found by lining up the graduated ring with the great circle and marking the position on the surface of the globe next to the graduation on the ring corresponding to the latitude for Sirius in the star catalog. Yellow or any other color that would contrast well with the dark background is suggested for indicating the stars, with a mark whose size indicates the magnitude (brightness) of the star. All the other stars in the star catalog are then to be placed on the globe by comparing their longitudes as given in the catalog with the longitude of Sirius given in the catalog, moving the graduated ring to the point on the ecliptic corresponding to this difference and then marking off the latitude either north or south as required. After all the stars are placed, the constellation outlines should be drawn in a color different from that of the ground, with simple, unobtrusive lines. Finally, the Milky Way is to be indicated on the surface of the sphere.

The larger ring is taken as a meridian ring and two pins are passed through holes bored at either end of its graduated half-circle. These pins are attached to the smaller ring so that the topmost (northern) pin is inserted at the marking of 66°9′ on the upper half of the small ring, thereby making the angle between the two poles correspond to the obliquity of the ecliptic as given by Ptolemy (23°51′). Having used the smaller ring for the purpose of determining the star positions, it would seem that Ptolemy intended for it then by some means not specified to be locked into a fixed position relative to the globe so that it would form the solstitial colure passing through the solstices, the equatorial poles, and the ecliptic poles (to which it is directly attached). This fixed position would then, according to Ptolemy, be valid for approximately 100 years, after which it would need to be reset.

This inner ring is to be set at that point on the globe's ecliptic that is as many degrees removed from the circle passing through Sirius as the latter circle is from the summer solstice for a particular date. Ptolemy gives as an example 12°20′ at the beginning of the reign of Antoninus Pius. The outer (meridian) ring is then placed within a horizon ring and can be adjusted within that ring for any given geographical latitude; the globe with attached inner ring appropriately set could be rotated east to west to imitate the movements of the heavens. The stars along the equator could be determined, according to Ptolemy, by observing which stars on the globe pass under the zero-point of the graduated half of the meridian (outer) ring; in a similar way the regions defined by the tropic circles can be seen under the points 23°51′ north and south of the zero-point of the meridian ring. The equatorial coordinate (declination) of a star, Ptolemy adds, can be read by rotating the globe so the star is alongside the graduated side of the meridian ring.

Such a description indicates that it was customary by the time of Ptolemy to place a meridian ring about a globe, which in turn was set into a horizon ring (see Chapter 2 of this study for further details on the use of meridian and horizon rings). Ptolemy does not provide any information on the processes involved in actually manufacturing such a globe, nor does he indicate what mechanism is to be used to allow the inner ring to rotate freely enough about the sphere so that it is useful for determining the positions of the stars, and yet later be rigidly fixed so as to serve as solstitial colure.

Ptolemy's design[53] for a celestial globe is unique in that the sphere has stars and the ecliptic but *not* the celestial equator and parallel circles; furthermore, there is an arrangement of rings that can be adjusted to any time period as well as any geographical latitude. As will be seen, such a design for a precession globe is not known to have been followed in the Islamic world even though the *Almagest* circulated widely and was for many centuries the fundamental astronomical treatise in Islamdom as it was in the West.

Unfortunately, there are few surviving Greco-

Roman celestial globes with which we might compare the later Islamicate ones. It is probable that most celestial globes produced in antiquity were made of wood[54] and thus have not survived the deterioration of centuries. All preserved globes, or fragments of globes, from Hellenistic and Roman times are non-functional, inaccurate celestial globes clearly made for decorative purposes and not for the use of an astronomer. All reflect the pre-Ptolemaic (or Aratean) design of a globe made for only one geographical latitude (bearing circles indicating the always visible and always invisible areas of the sky) and not placed in a meridian and horizon ring.[55] No remains are known of any armillary sphere or device for indicating the movements of the sun, moon, and planets,[56] nor of any attempt at a precession globe of the type described by Ptolemy. The Islamicate globes clearly represent the tradition of globe making current by the time of Ptolemy, which placed the sphere within a meridian and horizon ring.

The most famous example from the Greco-Roman world is the marble Farnese globe held by a kneeling figure of Atlas.[57] The globe itself is a Roman copy of a Greek original, while the figure of Atlas is a Renaissance addition. The marble sphere, 650 mm in diameter, shows 42 constellations (five additional ones, including Ursa Major and Ursa Minor, have been obliterated) carved in relief and viewed from behind (i.e., the human figures face into the globe). The globe bears five parallel circles: the celestial equator, the northern and southern tropic circles, and the two circles marking the always visible and always invisible areas. The ecliptic consists of three parallel circles, two about 6° to either side of the great middle circle. The two colures are also indicated. In these particulars the design follows Aratus's description. No star positions seem to be marked, though it is possible that they were painted on and have worn off with time. The position of the constellations with respect to the equinoxes suggests a date from the second or third century BC (roughly contemporary with the time of Hipparchus), while the execution of the piece seems to be no earlier than the first century AD, for which reason it is thought to be a copy. This globe, which is not a scientific instrument at all but a monumental decoration, was transferred to the Museo Nazionale, Naples, from the Palazzo Farnese in Rome, hence the common name Atlante Farnese.

Other artifacts from late antiquity, though not strictly celestial globes, are closely related in design if not in function. These remains include vessels for holding liquids, and zodiacal or astrological globes. Two hollow globes that served as vessels are known, one seen in AD 1888 outside a school building at Larissa,[58] and the other a fragment of a blue marble Roman vessel[59] with stars placed arbitrarily and with constellation figures chiseled out and originally inlaid with another material that has since fallen out. This fragment is especially interesting in that the Milky Way is indicated on it, but the placement of the constellations does not follow completely either Aratus nor Ptolemy. Four globes having only the 12 zodiacal figures decorating them are extant, including a marble one at Arolsen (160 mm in diameter),[60] which had an eagle perched on top, and a marble one (600 mm in diameter) at the Vatican,[61] which in addition has a few decorative stars dispersed over it.[62] The marble "astrological" globe from the third century AD found at the Dionysius theater in Athens is not a celestial globe at all, but bears various astrological and divinatory symbols.[63]

Celestial globes of the Aratean variety can be seen as a rather popular motif in frescos, statues, coins, and other works of art from the Greco-Roman world, in many cases intended probably as an allegorical representation of world or universal power. Such pictorial representations of pre-Ptolemaic celestial globes are well surveyed and illustrated by Thiele, by Schlachter, and by Gundel and Böker.[64] One gem of lapus lazuli is especially interesting in that it shows an astronomer sitting before a globe using a pair of drawing compasses to measure distances on the globe.[65] Though the gem carver has been precise about depicting the set of compasses, the circles on the globe make no sense; the globe is not set in horizon or meridian rings, indicating it is

supposed to be pre-Ptolemaic, and has no stars, which is quite common in these early artistic representations of celestial globes.

In the seventh century AD the Byzantine writer Leontius composed a treatise entitled *On the Construction of an Aratean Globe* (Περὶ κατασκευῆς Ἀρατείας σφαίρας) that is partially preserved today.[66] It is apparent that in his time globes were set within a meridian ring, which in turn was set within a horizon ring, for what he describes is a globe based on the design of Aratus but placed within a set of rings that were probably unknown to Aratus. Globes in Leontius's day were apparently not precession globes as described by Ptolemy, but bore on their surface the celestial equator as well as the ecliptic and stars—that is, the globes were basically of a type similar to the design evident in Islamicate celestial globes. Leontius constructed a globe for a man named Elpidas; its constellations and circles corresponded to those in the poem of Aratus. Leontius later set down a description of the globe for his friend Theodorus. He states that most of the globes of his day that he had observed agreed with neither Aratus nor Ptolemy. "For as you know all the spheres now produced agree reasonably well in most ways neither with Ptolemy nor with Aratus."[67] This statement may refer to there being no precession globes nor pre-Ptolemaic globes (those with star positions not based on coordinates) in his day, or perhaps refers to the inaccuracy of the constellation and star positions, which did not correspond to those given by either writer.

In speaking of the celestial globe described by Aratus, Leontius says:

> One must understand that the statements concerning the stars made by Aratus are not entirely correct, as can be seen from the expositions by Hipparchus and Ptolemy. The reason is that, first of all, Aratus for the most part followed the statements of Eudoxus, which are not very correct. Secondly, he delineated these things, not aiming at precise accuracy, as Sporos the commentator[68] says, but rather at usefulness for the navigators (ναυτιλλομένοι), and quite reasonably he treated them in a very general way. For indeed they navigate (οἱ πλωιζόμενοι) not by means of ingenious mechanical devices (διὰ μηχανικῶν ὀργάνων) and exact precision, but by means of unaided eyesight and observing in general terms the arrangement of the stars. Consequently the fabricated sphere is in no way useful for [determining] absolute fact, but rather very serviceable for understanding Aratean ideas. It is easy to learn at once the Aratean ideas (τὰ Ἀράτεια) which are not correct as well as to understand the truth of some of the statements.[69]

Leontius then reminds the reader that Aratus described the constellations not by coordinates, but by their spatial relation to one another, by their positions relative to the tropics, equator, and ecliptic, and by their rising or setting when various zodiacal signs rise or set. As an example of this he takes the constellation of Ophiuchus, the Serpent Charmer (see Figure 59). Aratus, according to Leontius, describes it in three different places—first, as having his head toward the head of "the kneeling man" (Hercules) with his feet on the chest and eye of the Scorpion, that he holds the serpent by the middle with the smaller part in the right hand and the larger part in the left hand (hence the figure is described as if facing into the globe), that the jaws of the serpent are close to the Crown, and that it has some bright stars at the shoulders and less bright ones at the hands; the Claws (Libra) are below the twists of the serpent. In a second place Aratus says it is cut at the shoulders by the winter tropic and at the knees by the equator. In yet a third place he states that at the rising of Cancer, Ophiuchus is set from the knees to the shoulders while dragging off the Serpent up to the neck and that when Scorpio is rising the head of the Serpent and Ophiuchus rise together, along with the hand of Ophiuchus and the first curve of the serpent; at the rising of Sagittarius the twists of the serpent rise with the body of Ophiuchus. After gathering similar information for each of the constellations from the poem by Aratus, the maker should note it down and set it aside for a later stage in the globe making.

Leontius then notes that Aratus described six circles that will have to be placed on the globe: the zodiac (ὁ ζωιδιακός, or ecliptic) and five parallel circles which consist of the celestial equator (ὁ ἰσημερινός), two tropic circles (θερινὸς/χειμερινὸς τροπικός), each 24° either side of the equator, and two circumpolar circles each 41° from the celestial poles. The latter two circles are the

"largest of the always visible" and "largest of the always invisible," which he notes are called the "arctic" and "antarctic" circles (ἀρκτικὸς/ἀνταρκτικὸς), denoting the areas of the sky that are always visible and never visible, respectively. Since these circumpolar circles are 41° from the poles, the globe Leontius is describing corresponded to the geographical latitude of Constantinople, which is probably where Leontius lived. In contrast to Leontius's interpretation, modern estimates of the area of constant visibility described by Aratus correspond to a terrestrial latitude between approximately 33° and 38°, that is, from Tyrus in Phoenicia to Athens. Leontius states that although Aratus does not specifically name these two circles, he does in effect describe them by delineating the portions of the constellations that are always visible, and which Leontius then concludes correspond to a 41° circumpolar circle. Leontius felt that the Milky Way (ἡ τοῦ γάλακτος ζώνη), on the other hand, though described by Aratus, ought not to be placed on a globe, for it is "neither uniform nor well-placed, but very varied in size, color, extent, and location."[70]

Proceeding to the actual execution of the globe, Leontius says to stain (? χρώσαντες) the sphere, if it is of wood (ξυλίνη), and smooth over it with plaster (γύψος), or wax (κηρός), thus mending the cracks in it if there should be any, and when quite dry to paint it (ἐπαλείψαντες) a deep color such as that called λαζουρίος (? azure) and set it aside till dry. He does not give any specific indication as to how the sphere is to be made nor why it would have cracks that need filling. He does not indicate whether it would be a solid or hollow sphere, whether in one or more pieces, nor whether it would be turned on a lathe for final smoothing and shaping. He does seem to imply that the sphere could be made of something other than wood.

After the sphere has been thus fashioned, there is to be set on supports a ring that will serve as the horizon (ὁρίζων), and which will enclose a second ring equal in size (and set at right angles to it in notches, cut in the first ring) which will serve as the meridian (μεσημβρινός) (see Figure 3). The inside radius of both rings is to be equally distant from the convex surface of the sphere and each ring is to cut the sphere into two halves. Furthermore, one half ("the semicircle above ground, as is customary") of the meridian ring should be divided by straight lines into 180°. Though he does not specify it, the meridian ring is to be attached to the sphere at two opposite points between which runs the 180° graduated half-circle.

Once the sphere is mounted inside the meridian ring, which in turn is nested in the horizon ring held horizontal by supports, then alongside the 41° mark on the graduated half-circle of the meridian ring, a sharp needle (βελόνη) is held perpendicular to the surface of the sphere and is made to penetrate into the colors, that is, the surface paint and plaster. Then as the sphere is turned one full revolution, the sharp point will trace on the sphere a circle which will be equivalent to the "arctic" circle. At a point 90° distant from both the north and south poles, another circle can be traced, which will be the (celestial) equator, while another circle 41° from the south pole is etched in a similar manner. Then at 24° from the equator the maker traces by the same method the summer tropic on the northern hemisphere and the winter tropic on the southern hemisphere.

Leontius then says to find a point on the surface of the sphere 24° from the north pole (equal to the distances of the tropics from the celestial equator and hence the obliquity of the ecliptic). This point will serve as the pole of the zodiacal circle. Leontius does not give details for tracing the great circle of the ecliptic, but one may assume that the sphere would be realigned and attached to the meridian ring at the new poles 24° distant from the first set, and the circle traced alongside the 90° mark of the ring in a manner similar to the preceding tracings. If the sphere were left to rotate in the meridian ring at the celestial equatorial poles, the simple rotation and use of the graduations on the meridian ring could not be used to trace the ecliptic as with the previous circles. Leontius states that the zodiac will touch the tropics and be divided into two equal parts by the equator. Once the circle is drawn, it is to be divided into 12 parts, with the

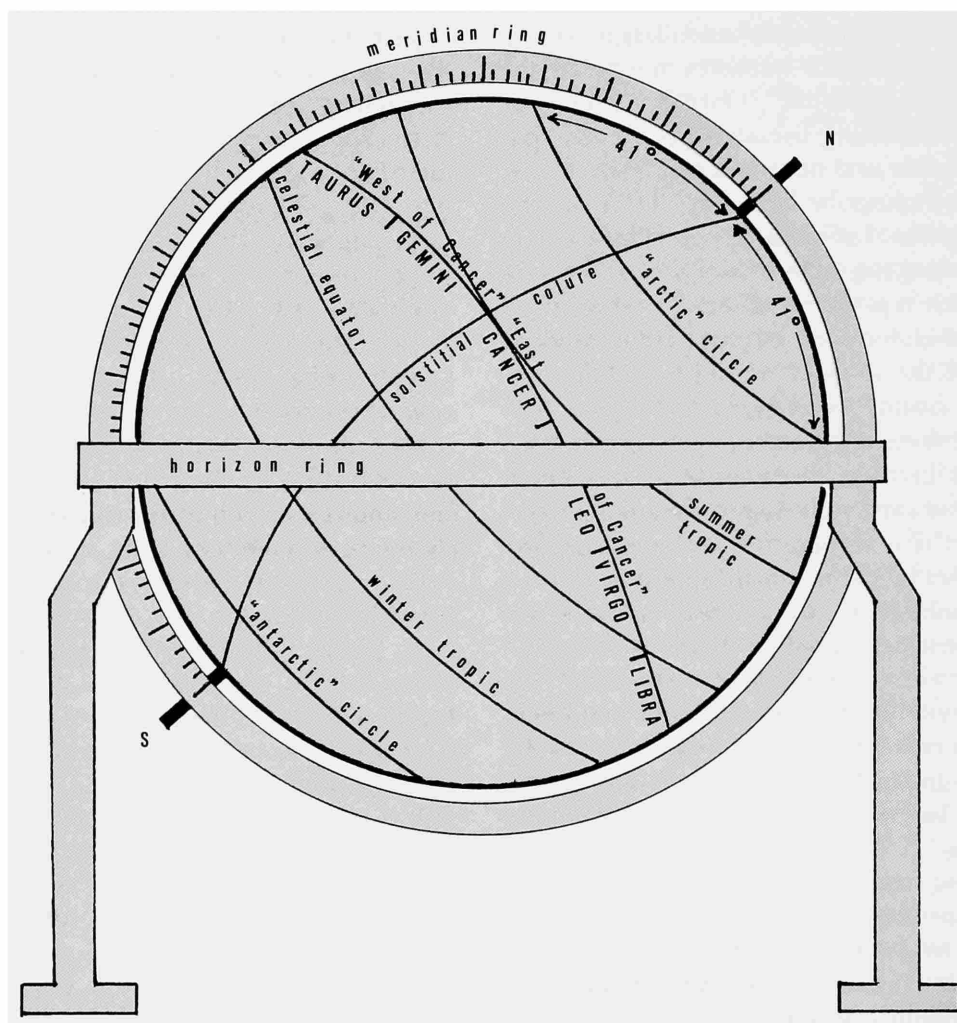



FIGURE 3.—Basic design of an "Aratean" celestial globe constructed by Leontius in the seventh century AD.

points of contact with the tropics and the equator being points of division.

Each of the six circles is to be distinguished by a color different from that of the base color—that is, the incised circles are to be painted over with a contrasting color. Then the names of the twelve zodiacal signs are to be painted using a light color (ἀερίῳ χρώματι) that can be easily removed, beginning with Cancer at the point where the zodiac touches the summer tropic and working eastward with Leo, Virgo, and so on. Although it is not stated in the tract, it is assumed that at this point the constellations and stars would be indicated on the globe using the information gleaned from the Aratus text.

That done, if the meridian ring with the enclosed sphere is placed in the horizon ring so that, when revolved, the "arctic" and "antarctic" circles touch the horizon ring on the upper northern side for the "arctic" and on the lower southern side for the "antarctic" (set for a geographical latitude of 41° north), it will be evident, Leontius says, that the two tropics will be cut by the faces of the horizon ring in a ratio of 15:9. That is to say, he continues, that since one day and one night (τὸ νυχθήμερον) consist of 24 hours (ὧραι), the summer tropic will show 15 hours above the horizon on the longest day and

9 below for the shortest night; this will be the inverse for the winter tropic, which will have 9 above for the shortest day and 15 below for the longest night. This relation of 15:9, Leontius notes, is the same as the 5:3 division of the summer tropic given by Aratus.

In the last section of the treatise Leontius states that the sphere should be placed in the stand "along the pole (*τρόπος*) of the equator"—that is, with the globe attached at the celestial poles to the meridian ring and the ring rotated within the horizon ring so that the axis of the globe is horizontal. Then the sphere is turned until the beginning of the division of the ecliptic belonging to Cancer appears at the eastern edge of the horizon ring. The sphere is to be made secure and immobile "with wax or some such thing" and a circle inscribed with the sharp needle on the surface of the sphere alongside the entire circumference of the horizon ring—thus producing on the globe the solstitial colure, which, however, remains unnamed. Leontius instructs the maker to label the semicircle (of the ecliptic) to the east of this new great circle "East of Cancer" using small letters, and that to the west, "West of Cancer."

It is curious that Leontius would have placed an Aratean globe, which was constructed for only one geographical latitude, into a meridian-horizon ring assembly. He must have realized from Ptolemy's *Almagest*, cited several times in his treatise, that the rings allow for adjustment to different latitudes. It is implied in Leontius's treatise that the globe is to remain set for only the one given latitude, in this case that of Constantinople, and not adjusted for other latitudes. Even held at that one position, however, the horizon and meridian rings make the arctic-antarctic circles redundant. This treatise represents an interesting compounding of pre-Ptolemaic principles with a design that was apparently common by the time of Ptolemy.[71]

A Greek celestial globe was described in the twelfth century by the astronomer Ibn al-Ṣalāḥ, who said he saw it, probably in Baghdād, where he worked for most of his life. This globe, according to Ibn al-Ṣalāḥ, had the stars positioned so that their longitudes were increased 6° over those in the *Almagest* of Ptolemy, in which case (taking a value for precession common in antiquity of 1° per 100 years) the globe would be datable to around AD 738.[72] Unfortunately, Ibn al-Ṣalāḥ does not provide us with further details concerning the design of the globe, or whether it had rings.

In a ninth-century copy[73] of the astronomical poem by the Augustan poet Hyginus, there occurs a schematic drawing of a celestial globe mounted in a meridian ring by a pin at the northern equatorial pole. The meridian ring is supported at the nadir by a small decorated column and rests in a horizon ring drawn to resemble a Greek building having six Corinthian columns. The globe itself has a wide zodiacal band with the zodiacal constellations drawn in it (Gemini, Taurus, and Aries showing), with three additional northern constellations and three southern drawn on it; no stars are indicated. The human figures are still drawn facing into the globe. The illustration is labeled *Involutio spherae*, which is the name of a late Greek school poem appended to the poem by Hyginus.

By the ninth century AD it is evident that in the Islamic world[74] all celestial globes are to be mounted in two graduated rings and made adjustable to different geographical latitudes—a basic design apparently common by the first century AD. On all globes described in Islamicate treatises, as well as all the ones preserved today, both ecliptic and equator, nearly always graduated, are indicated directly on the surface of the globe, so that none are precession globes as described by Ptolemy. On all extant Islamicate globes that have the constellation outlines on them, the human figures face outward toward the person using the globe rather than in toward the globe with their backs to the observer as was apparently, from our very fragmentary evidence, commonly done in the Greco-Roman and Byzantine worlds. On every Islamicate globe preserved today there is a set of six great circles at right angles to the ecliptic. When and where this first became customary is unknown. Meridians, with the occasional exception of the two colures, were

not usually indicated on Islamicate celestial globes (the exceptions being nineteenth-century products), just as apparently they generally were not on Greco-Roman globes.

The earliest extant Islamicate constellation images are to be found in a cupola of the palace of Quṣayr ᶜAmr located in the desert about 50 miles east of the north end of the Dead Sea. The small palace was built between AD 711 and AD 715 by al-Walīd I to commemorate his victories,[75] and had a bath consisting of three rooms, one tunnel-vaulted, one cross-vaulted, and a third covered by a dome. The dome of this *calidarium* was decorated to resemble the vault of heaven, with the northern and zodiacal constellations plus some southern ones depicted on it, and the northern celestial pole directly overhead. Consequently, it displayed a larger portion of the sky than could be observed at any one time from one location on the earth.[76]

The design of this fresco presents an interesting blending of late classical and Byzantine traditions with some early Islamicate influences,[77] and is of interest to us as evidence of a transitional period in celestial globe design. The iconography of the majority of the constellation figures (many of which have been badly defaced) appears to be very closely related to illustrations of constellations found in two late Greek manuscripts, one of the ninth century and one of the fifteenth century,[78] as well as to some features of those on the Farnese globe, indicating a continuous Hellenistic and Byzantine tradition.

The maker also reflects some Hellenistic influences in drawing the human figures slightly turned into the globe (or in this case into the surface of the dome), and in representing the ecliptic as a wide band with a center circle and two parallel circles about 5° or 6° to either side. Yet three figures (Cepheus, Boötes, and Orion) are depicted in a manner not seen in Greek sources, but which is found on some of the later Islamicate celestial globes.[79] Moreover, there are a set of six great circles that pass through the ecliptic poles and divide the ecliptic into twelve parts (little more than the northern semi-circles of each great circle is actually indicated on the dome). These ecliptic latitude circles[80] are not to be found on any of the few Greco-Roman artifacts or drawings of celestial globes or planispheric star maps, and of course are not in manuscript illustrations of the individual constellations. They are, however, to be found on all extant Islamicate globes.

Of particular interest is the fact that the painter of this fresco has not designed it so that you view the constellations as you stand under the dome in the same way that you would see them overhead in the sky. Instead he has reversed left to right each constellation figure and the entire order of the constellations—that is, he has drawn the constellations as you would see them looking down on a celestial globe rather than up into the sky. Thus the possibility arises that he was using an early celestial globe as a guide to the constellations rather than manuscript illustrations. Yet the model of a celestial globe does not completely account for the spacing of the constellation figures. It is also evident that the artist did not fully understand the technical significance of certain details, for the circle of the ecliptic was not made to pass through the northern solstitial point, possibly to avoid a window in the dome; some of the constellations are crowded and poorly positioned.

In addition to the ecliptic latitude circles intersecting at the north ecliptic pole, there are also a series of concentric circles having the celestial (equatorial) pole as the center which, in the dome, is directly overhead. There are six prominent circles painted dark brown. The smallest in the center is the equatorial polar circle passing through the ecliptic pole about 23½° distant—that is, what we today call the arctic circle. There is a circle representing the equator, with one circle inside it representing the northern tropic and one representing the southern tropic outside it, and between the polar circle and the northern tropic are two nearly equidistant circles. Then there are three additional concentric circles evenly spaced between the northern tropic and the second circle from the center; these circles are very pale and appear to have been painted over and were possibly preliminary attempts of

the artist to get the spacing on the dome as he wanted it. The edge of the domed ceiling is another of the concentric circles, equivalent to about 40° south of that representing the equator. The polar circle is a common feature of extant Islamicate celestial globes, while there is no mention of it in Hellenistic, Roman, or Byzantine sources.

Such concentric circles are to be found in two ninth- or tenth-century Latin drawings of planispheric star maps,[81] which show the constellations with great distortion in five concentric circles representing in the center the area bounded by the equatorial polar circle, then the northern tropic, the celestial equator, the southern tropic and the southern polar circle forming the outside border of the planispheric map. The ecliptic is represented by a wide circular band apparently off-center around the ecliptic pole; there is also a second apparently off-center circle, which is the Milky Way.

As has been suggested,[82] such a stereographic projection of the heavens to form a planispheric star map must have been similar to the model the artist at Quṣayr ᶜAmr employed, for at first sight these two maps appear to be very much like the dome. There are, however, differences. The order of the constellations on the manuscript planispheres is that which would be seen in the sky—that is, they are not reversed as would be seen on a globe or as the painter of the dome depicted them. Secondly they lack the ecliptic latitude circles. Furthermore, they depict the Milky Way, which is not painted on the dome.

If we assume, however, that what the painter of the Quṣayr ᶜAmr dome employed as a guide was not a stereographic projection of the heavens quite like those in the two extant manuscript planispheric maps, but rather was a stereographic projection of a celestial globe, then all the features of the dome are quite easily accounted for. The arrangement of concentric circles about the overhead celestial pole and the spacing of the constellation figures would be accounted for by the method of stereographic projection using equidistant representation of the circles of declination; the ecliptic latitude circles are an integral part of later Islamicate globe design and were probably common in this period as well. We have no evidence that the Milky Way was ever indicated on a globe (except for Ptolemy's precession globe, which appears to have had little or no influence on subsequent globe design), so its omission would be consistent with a globe having been the basis of the stereographic projection.

If we accept such a conjecture, then we can conclude that in the eighth century in Syria celestial globes were being drawn with the ecliptic latitude circles so characteristic of the later extant globes, and that planispheric star maps drawn in stereographic projection were, if not common, at least available. If this were true, then this dome would provide evidence for the survival of techniques of stereographic projection in the provinces of the Roman and Byzantine empires before the earliest extant astrolabes and before the translation of Greek texts into Arabic. In this context it is worth noting that the palace of Quṣayr ᶜAmr was built in the same region where some six to seven decades earlier, the Syriac scholar Severos Sēbōkht wrote a Syriac astronomical text based on Greek sources and a treatise on the astrolabe.[83]

At the end of the eighth century two Persian astronomers working in Baghdād were responsible for introducing into Islamicate astronomical literature the Sanskrit astronomical Siddhānta texts which dated from no later than the first half of the fifth century AD. The two astronomers were Yaᶜqūb ibn Ṭāriq, who died about AD 796, and Muḥammad ibn Ibrāhīm al-Fazārī (died ca. AD 801–802), who was assigned by the Caliph al-Manṣūr the task of translating the texts into Arabic. Five Siddhānta texts, which incorporated many Hellenistic astronomical practices, were summarized by Varāhamihira in the sixth century AD. In this extant Sanskrit summary by Varāhamihira there is a brief and rather obscure mention of a celestial globe, which the older translation says was to be made simply "of some material," while the more recent translation says it is to be "of wood."[84] The globe has the equator and ecliptic indicated, and apparently the ecliptic

(or possibly the equator) is graduated. No rings are mentioned, but it is stated that the globe should be tilted to the north by an amount equal to the terrestrial latitude. Then a technique is mentioned that is apparently similar to that discussed in Chapter 2 for finding how much time had elapsed on a certain day, given the position of the sun in ecliptic, the ascendant, and the latitude of the town. The short reference in the Sanskrit text is quite obscure, however, and can be interpreted differently.

About one hundred years after the building of Quṣayr ʿAmr the Arabic translation of Ptolemy's *Almagest* was completed in Baghdād by al-Hājjaj ibn Yūsuf ibn Maṭar, who may well have used an earlier Syriac version by Sarjūn ibn Halīyū al-Rūmī. A more authoritative version of this important treatise was prepared in AD 827–828 by Isḥāq ibn Ḥunayn ibn Isḥāq for the Caliph al-Maʾmūn and corrected by Thābit ibn Qurra.[85] The Arabic version of the *Almagest* was an important source for the star positions and constellation shapes for Islamic globe makers, for it contained tables of latitudes and longitudes for each individual star and described its position in relation to 48 constellation outlines. The description of the stars in terms of the constellations was intended as an *aide-mémoire* to the general location of the stars and not a substitute for the precise charts of coordinates. Some of the extant Islamicate globes specifically state that they were based on the coordinates in Ptolemy's *Almagest* (Nos. 2 and 3 of the catalog). The celestial globe described by Ptolemy, however, seems to have had little influence on later globe design.

Early in the ninth century the well-known instrument maker ʿAlī ibn ʿĪsà made a large celestial globe.[86] Though he worked in Baghdād and Damascus, it seems that an even more important Islamicate center of scientific instrument making was the city of Ḥarrān[87] lying between the northern reaches of the Euphrates and Tigris rivers southeast of Edessa. The tenth-century author of the *Book of the Constellations of the Fixed Stars*, ʿAbd al-Raḥmān al-Ṣūfī, speaks of having seen many celestial globes executed by people from Ḥarrān.[88] Qurra ibn Qamīṭā al-Ḥarrānī is said[89] to have made a model of the world (*ṣifat al-dunyā*, a terrestrial globe?), which the scholar and translator Thābit ibn Qurra al-Ḥarrānī copied. It was made of Dubayqī cloth (named after a town in Egypt), which was well-known throughout North Africa and Syria. The cloth was of unbleached fiber with waxed dyes. The twelfth-century astronomer Ibn al-Ṣalāḥ who worked in Baghdād mentions using a celestial globe of Ḥarrānian origin.[90]

In Ḥarrān in the latter part of the ninth century, the influential astronomer al-Battānī (known in the Latin world as Albategni or Albatenius)[91] wrote a comprehensive astronomical treatise which included star catalogs and planetary tables. In this extensive tract al-Battānī describes in detail a celestial globe that is suspended in five rings.[92] To make this instrument, which he calls *al-bayḍah* (the egg), take "a sphere of copper (*nuḥās*), adjudged quite round, well-executed in every direction, smooth of surface, turned on the lathe (*makhrūṭah fī al-shihr*) and of whatever size you wish."[93] He does not supply any information on how this sphere of copper is to be constructed, nor if it is solid or hollow. Once the sphere is obtained, the maker is to determine two points diametrically opposite on it, which will serve as poles and inscribe a circle having these points as poles and cutting the sphere in half. This circle is then divided into four equal parts, which are marked by a dot. Taking one of the dots as the center, a second great circle is inscribed, which will pass through the first two poles and cut the first circle into two opposite halves (this second great circle will become the solstitial colure). Then the maker is to divide one of the quadrants of the first circle (which will eventually serve as the celestial equator) into 90 equal parts.

Using this graduated quadrant as a measure, a drawing compass (*midwār*) is set to equal the obliquity of the ecliptic, which al-Battānī specifies as 23°35′. The maker is then to set one end of the compass on one of the two poles and inscribe with the other end a circle around the pole; the procedure is repeated with the second pole. (Thus two equatorial polar circles are drawn that

pass through the ecliptic poles; the obliquity of the ecliptic can, of course, only be approximated to the nearest degree, since the quadrant of the equator used as a scale has only 90 divisions.) These two lesser circles will intersect the second great circle at four places; two of these points of intersections diametrically opposite each other are then taken as a set of poles for a third great circle, which will be the ecliptic. The circle that passes through all four poles, al-Battānī notes, is called the Circle of Cancer and Capricorn (the solstitial colure, which was the second great circle to be inscribed on the sphere). The point where this circle intersects the ecliptic above and to the north of the equator is labeled the "Point of the Start of Cancer" and the point below the equator the "Point of the Start of Capricorn." The two points where the ecliptic and equator meet are labeled the "Point of the Start of Aries" and the "Point of the Start of Libra" (see Figure 4). Then the maker writes the names of the zodiacal houses along the ecliptic, allotting three houses to each quadrant. Each house has six sections of 5° each, with each section or interval numbered with the *abjad* letters (*bī ḥurūf al-jummal*)—that is, instead of standard numerals, letters of the alphabet with recognized numerical values were employed. Al-Battānī notes that the ecliptic is to be numbered, with 5° through 30° indicated for each of the twelve houses while the equator is to have 72 sections of 5°, each section numbered from 5° through 360°, beginning at the "Point of the start of Aries."

Al-Battānī continues by giving instructions for determining star positions on the globe. The maker is to take from the graduated scale of the equator with the drawing compass the amount equal to the stated latitude of the star. Then with

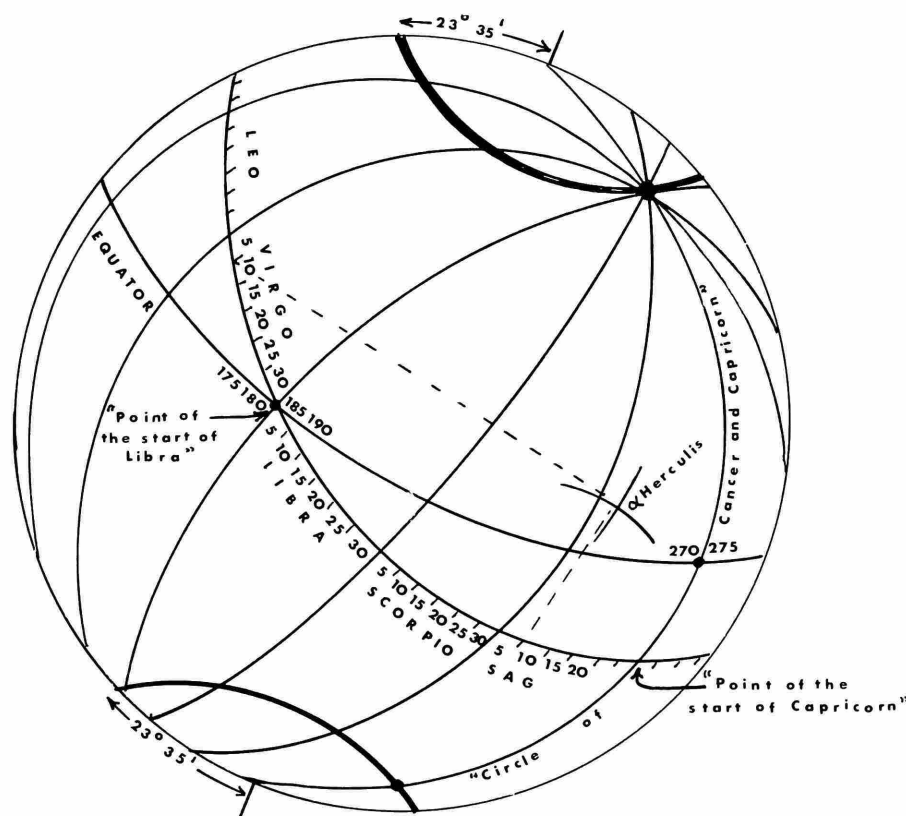



FIGURE 4.—The celestial globe described by al-Battānī in the ninth century AD, showing the determination of a star position.

the compass thus set, one end of the compass is set "on the degree in which the star is" (i.e., its longitude reading along the ecliptic), and the other end used to trace an arc in the general area of the latitude "with an obscure line which will leave no trace on the sphere." Then the drawing compass is opened and its two heads set at an amount equal to 90° of the equator. With it thus adjusted, one end of the compass is placed at a point along the ecliptic, which is 90° distant from the longitude, and the other end used to inscribe an arc that will necessarily intersect the first arc at a point that will be the position of the star (see Figure 4).

Al-Battānī does not cite a specific example. Figure 4, however, demonstrates his technique with the star *α Herculis*, whose coordinates might be given as latitude 37°30′N and longitude Sagittarius 5°22′. Since the smallest graduations on the globe are single degrees, the positions can only be approximated to the nearest degree or half-degree. First, with the compass set at 37°, based on the graduations of the ecliptic, one end would be placed at 5° of the House of Sagittarius and an arc lightly inscribed toward the north. Then with the compass set at 90°, a second arc would be inscribed with one end of the compass set on 5° of the House of Virgo (that is, 90° distance from the longitude of Sagittarius 5°). The point of intersection is *α Herculis*. The manner of marking the stars on the sphere, whether with incised circles or Xs, or with inlaid silver points, is not specified by al-Battānī.

Following the placement of as many stars as one wishes on the sphere, the maker, according to al-Battānī, should then incise on the globe a great circle passing between each zodiacal house and through the ecliptic poles (resulting in a set of six great circles serving as ecliptic latitude circles).

This sphere, according to al-Battānī, is then to be set within a set of five copper (*nuḥās*) rings (see Figure 5 for an illustration). One ring serves as a horizon ring; two rings nested one within the other together serve as the meridian ring, the inner ring to which the sphere is attached at the celestial poles being movable and other ring stationary. A stationary ring at right angles to both the meridian and horizon rings marks the zenith and nadir and east-west points of horizon. These rings with enclosed sphere rotate within a larger fifth ring, by which the assemby can be suspended. This outside ring has a slot cut through the thickness of one of the upper two quadrants, through which a pointed gnomon can be inserted and adjusted to different positions.[94] The details of the design and construction of these rings described by al-Battānī and the use of the gnomon will be discussed in Chapter 2.

With this detailed account of a celestial globe by al-Battānī we have moved completely away from the pre-Ptolemaic designs of celestial globes, which were characterized by the five parallel equatorial circles and an emphasis on constellation outlines rather than precision of star positions. This globe of al-Battānī's has the ecliptic latitude circles characteristic of all Islamicate celestial globes and the star positions determined by coordinates; in fact, he does not even mention the depiction of the constellation outlines. The majority of extant Islamicate celestial globes are missing the rings, but among those that do possess them still, all but one have the horizon ring fixed to a stand and consequently do not have the outside fifth ring nor the adjustable gnomon. The one exception is globe No. 5 of the catalog, made at the end of the thirteenth century. Its horizon ring, to which the meridian ring and zenith rings are attached, is suspended rather than resting on a stand, much as al-Battānī described, but without the outside fifth ring. The zenith ring appears to rotate about the globe, however, and to have a slit running through the thickness of the upper quadrant parallel to the face of the ring, through which perhaps a needle-like gnomon could have been placed, although the ring is perhaps a bit closer to the surface of the sphere than al-Battānī intended his outside ring to be. Nonetheless these unusual features of a slit in a rotatable zenith ring and a horizon ring that was intended to be suspended make this globe the closest extant artifact to the design detailed in the ninth century by al-Battānī.

Toward the end of the ninth century a Christian from Baalbek in Syria, Qusṭā ibn Lūqā al-Baᶜlabakkī, lived and worked in Baghdād and

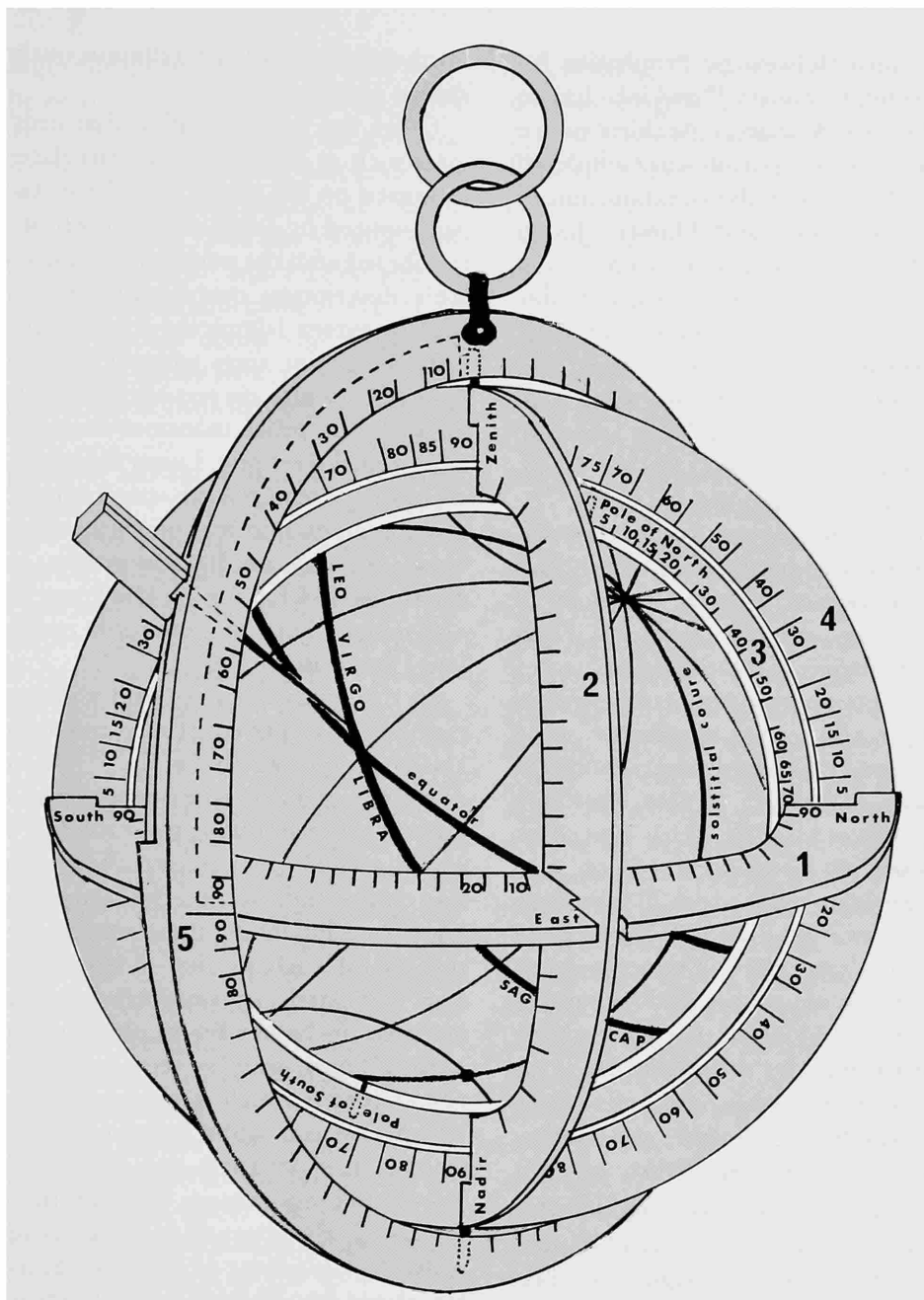



FIGURE 5.—The celestial globe of al-Battānī, mounted with five rings and a gnomon. Horizon ring = 1, zenith ring = 2, moveable meridian ring = 3, stationary meridian ring = 4, and outside ring carrying gnomon = 5.

Armenia.[95] In addition to translations from Greek and Syriac into Arabic, Qusṭā ibn Lūqā composed several medical and astronomical treatises, including one *On the Use of the Celestial Globe* (*Kitāb fī al-ᶜamal bi-l-kurah al-nujūmīyah*), which is still preserved today.[96] This treatise is of considerable importance to our knowledge of the purpose and practical value of such globes to astronomers (see Chapter 2), and it was translated into Latin by Stephanus Arnaldus as *De*

sphaera solida,[97] into Hebrew by Prophatius Judaeus in the thirteenth century,[98] and into Italian in 1341 by Maestro Bernardo Arabico ouero Saracino.[99] A Spanish translation was completed by February of 1259 under the collaboration of Jehuda ben Moses Cohen and Maestre Johan Daspa, clérigo del rey. This version can be found in the translations and compilations from Arabic astronomical studies known as *Los libros del saber de astronomia* prepared for Alfonso el Sabio, who in 1251 had been crowned Alfonso X of Castile.[100] A treatise on the use of the spherical astrolabe has been attributed to Qusṭā ibn Lūqā, although his authorship is questioned today.[101]

The first four chapters of the Spanish translation of the treatise on celestial globes, titled *Libro del alcora*, are concerned with the methods of constructing a globe—a topic Qusṭā ibn Lūqā had ignored in his original treatise (see Chapter 2). These four chapters were presumably written by the translators, and a final chapter on some astrological uses was composed by an unidentified "Don Xosse al-faquin" (? Don José the learned [faqīh] or Don José the fakir). The celestial globe as described by Qusṭā ibn Lūqā is to be set inside a meridian ring, which in turn rests in a horizon ring on a stand (*kursī*). Both of the rings are graduated into 360°. The material of the globe and rings is never specified, though at one point there is a mention of placing the *stone* into the horizon ring. The meridian ring is attached by two pins to the equatorial poles of the globe. The globe itself has an ecliptic and equator drawn on it, both graduated into 360°. At right angles to the ecliptic are six great circles that divide the ecliptic into the 12 zodiacal houses, and the names of the zodiacal signs are then written along the ecliptic, one at each 30° division. "Circles of the two poles of the ecliptic" and "circles of the two poles of the equator" are then drawn; thus there are four polar circles: two having the equatorial poles at the center and the circumference passing through the ecliptic poles, and two centered at the ecliptic poles and passing through the equatorial poles. All four have a radius equal to the obliquity of the ecliptic whose value is not specified by Qusṭā. Tropic circles are not indicated, and constellation outlines are not drawn on the globe.

Qusṭā ibn Lūqā specified that only the bright stars such as those used on astrolabes are to be indicated on the globe, and these stars are to be represented by small circles, each of which is to be labeled with the name of the star it represents. This description corresponds with a common type of extant Islamicate celestial globe bearing only the major stars without constellation outlines. Qusṭā also directs the maker to place the names of 28 lunar mansions inside small circles alongside the ecliptic. Lunar mansions are a characteristic of early Arab, pre-Islamic astronomy and astrology and are of very ancient, possibly Mesopotamian or Indian, origin (see "Lunar Mansions" in Chapter 5). The lunar mansions are occasionally but not commonly indicated on extant Islamicate globes.

In the tenth century ʿAbd al-Raḥmān al-Ṣūfī (AD 903–986) was court astronomer to ʿAḍud al-Dawla in Iṣfahān in Persia.[102] He composed a most important treatise consisting of a commentary on the star catalog presented by Ptolemy, in which al-Ṣūfī gives information on pre-Islamic star names and on some stars not listed by Ptolemy. Accompanying the commentary were illustrations of each of the 48 constellations (with stars indicated and numbered in each) as they are seen in the sky by an observer on earth (*fī al-samāʾ*) and again as seen on a celestial globe (*fī al-kurah*) which is to say reversed right to left, and also a slight revision of Ptolemy's star catalog in chart form (see Classical Greek and Pre-Islamic Sources in Chapter 5). This work, entitled *Kitāb ṣuwar al-kawākib al-thābitah* (*Book of the Constellations of the Fixed Stars*), was also translated into Persian in the thirteenth century by the astronomer Naṣīr al-Dīn al-Ṭūsī and at least twice again in the seventeenth century.[103] A considerable number of illustrated copies, both Arabic and Persian, are preserved today, the earliest being one copied by his son in AD 1009–1010; there is also an Arabic copy and a Persian version, both having the autograph of the fifteenth-century astonomer Ulugh Bēg.[104]

This treatise by al-Ṣūfī was no doubt an extremely important source for the design of con-

stellation images for globe makers, and the illustrations in the manuscript copies reflect the dress and artistic conventions of different locations in the Islamic world and time periods, just as do the depictions of the constellation figures on extant Islamicate celestial globes. The star catalog presented by al-Ṣūfī, moreover, was a direct source for at least four of the extant globes (Nos. 6, 7, 8, and 62), and was no doubt the source of coordinates for many other makers who did not choose to put such an acknowledgement on their globe.

Al-Ṣūfī speaks of having seen a book on constellations by ᶜUṭārid.[105] He claims that it contained errors,[106] and also attacks the earlier astronomical work of al-Battānī.[107] He notes errors on the large celestial globe made by ᶜAlī ibn ᶜĪsà a century earlier, and says he has seen many globes made by makers from Ḥarrān. Al-Ṣūfī criticises those celestial globes, which he calls *kurāt muṣawwarah* (decorated globes) made by makers who did not know the true positions or magnitudes of the stars. He goes on to say, however,[108] that many globe makers used star catalogs, such as the *Almagest* of Ptolemy, for the longitudes and latitudes of the stars, changing the longitudes to correct for the intervening time interval, but did not realize that when compared with the actual observations of the stars in the sky the coordinates were incorrect. By this remark al-Ṣūfī seems to be criticizing the reliability of the available star catalogs.

According to the scholar al-Bīrūnī,[109] al-Ṣūfī told the geometer Abū Saᶜīd Aḥmad ibn Abī al-Jalīl al-Sijzī (ca. AD 951–1024) that he, al-Ṣūfī, laid very thin paper on a celestial globe and fitted it carefully over the surface of the sphere and then traced on the paper the constellation outlines and individual stars as precisely as the transparency of the paper would allow. Such a procedure was probably used by al-Ṣūfī only to obtain the drawings of the constellations that accompany his book, and these illustrations of the constellations and stars give only approximate relationships and positions; the precise positions are obviously to be taken from the accompanying star catalog, where they are given in angular measurements. Al-Bīrūnī, however, goes on to criticize al-Ṣūfī for thinking that you could accurately transfer spherical measurements onto a plane surface by simply tracing the positions on a piece of curved paper and then straightening it out. Al-Bīrūnī then uses this criticism as a starting point for his own treatise on stereographic projection, by which one can with mathematical methods accurately project spherical coordinates onto a plane, as is done in designing an astrolabe.

All such statements by al-Ṣūfī imply that celestial globes were not uncommon in the ninth and tenth centuries, though none from that period are known to be extant. It may well be that some were of a considerably larger size than any from the Islamic world still preserved today. In the same treatise on stereographic projection, al-Bīrūnī says that celestial globes are preferable to illustrated texts because the constellations are positioned around each other and in correct proportion, but "that it does not work well on small globes, but only on large ones; but these are rare and costly and too large for carrying and transporting on journeys, so that just as their usefulness surpasses [that of the book], the difficulty involved in the use of these instruments counterbalances these advantages."[110]

Al-Ṣūfī prepared a treatise on the use of celestial globes[111] and is reported to have constructed a celestial globe himself. A maker of astrolabes and celestial globes in Fāṭimid Egypt said that in the year 435 H/AD 1043 he saw in the library in Cairo (*Khizānat al-Kutub bi-l-Qāhira*) "a celestial globe (*kurah*) of silver (*fiḍḍah*) made by al-Ṣūfī for the ruler ᶜAḍud al-Dawla, and its weight was 3000 dirhams [silver coins weighing about one-eighth of an ounce] and so it had been sold for 3000 dinārs [gold coins]."[112]

The renowned late ninth- and early tenth-century scholar al-Bīrūnī is of interest to the history of celestial globes not only because of his comments concerning globes in his treatise on stereographic projection, but also because he presented a star catalog that may have influenced makers of celestial globes. Furthermore, in some of his writings he not only discussed the constellations in general, but also lunar mansions that occur on some globes. These treatises are impor-

tant sources of information for the history of star names and lunar mansions.[113] One manuscript of such a treatise is illustrated with drawings of constellations having stars placed in them similar to those illustrating al-Ṣūfī's treatise.[114]

No Islamicate globes predating the eleventh century are known to exist today. The earliest preserved Islamicate globe (No. 1 of the catalog) was made in Valencia in Spain in AD 1080 (or 1085) by a leading astrolabe maker Ibrāhīm ibn Saᶜīd al-Sahlī al-Wazzān with the collaboration of his son Muḥammad. The inscription in Maghribī (western) Kūfic script informs us that the globe with stand (*al-kurah dhāt al-kursī*) was made for the holder of the dual office of wazīr (*dhū al-wizāratayn*, or wazīr of war and wazīr of peace), the supreme commander-in-chief Abū ᶜĪsà ibn Labbūn, and that the fixed stars were placed on it in proportion to their magnitudes (each indicated by a dot made in an engraved circle). The globe is a hollow metal globe made in two hemispheres with the seam along the equator. It has 1015 stars with 47 labeled constellations[115] conforming to the basic designs as described by al-Ṣūfī, but drawn in a style rather different from that appearing on most of the other preserved Islamicate globes. Most of these globes come from the eastern rather than the western part of the Islamic world.

The globe has a graduated ecliptic and equator and six great circles passing through the ecliptic poles (ecliptic latitude circles), but no polar or tropic circles. The stand and rings are not the original ones. The date of completion given on the globe has been read as the first of Ṣafar 473 H, (or 22 July AD 1080) and as the first of Ṣafar 478 H, (or 28 May AD 1085). The dot under the final *abjad* numeral is not sufficiently defined to make absolutely certain whether the letter is a *ḥāᵓ* (=8) or a *jīm* (=3). Ibrāhīm ibn Saᶜīd al-Sahlī is known to have been a prominent instrument maker working in Valencia and Toledo, for a mention of him among the mathematical scholars in Andalusia occurs in *The Book of the Categories of Nations* written by Ṣāᶜid al-Andalusī in AD 1068.[116] At least four astrolabes dated from AD 1067–1086 are still known today.[117]

A very similar globe having no date or maker's name on it is now at the Bibliothèque Nationale in Paris (No. 34 of the catalog). It is written in a western (Maghribī) form of Kūfic script. In design and star positions it closely resembles the one signed by Ibrāhīm ibn Saᶜīd al-Sahlī.

From the twelfth century there remain today two Islamicate globes. The earlier of the two (No. 59) is of the style in which only the major stars or small star groups are represented, in this case about 50 in all, including the 28 lunar mansions. Inlaid silver points are used to mark the stars, but there are no constellation outlines. The globe is metal with a seam along the ecliptic and is inscribed in the eastern form of Kūfic script. The maker is stated to be Badr ibn ᶜAbdallāh Mawla Badīᶜ al-Zamān, who constructed the globe in 535 H (or AD 1140–1141) making it the earliest extant globe from the eastern part of the Islamic world. The globe is curious in that the only way of mounting it is apparently at the ecliptic rather than equatorial poles. The meridian ring is a recent replacement, but the horizon ring may be contemporary with the globe.

The expression *badīᶜ al-zamān* at the end of the maker's name means "marvel of the age," and was an epithet given Hibat Allāh (died AD 1139–1140). An outstanding scholar of Baghdād who spent his last years in Iṣfahān, he was considered the best astrolabe maker of his day.[118] The word *mawla* can mean an assistant or an apprentice, so that we might conjecture that Badr ibn ᶜAbdallāh had been an apprentice to Hibat Allāh, which was such a great distinction that he wished to retain the title even after the death of Hibat Allāh. There is one astrolabe made in AD 1130 signed by Badr Mawla Badīᶜ al-Zamān Hibat Allāh ibn Ḥusayn al-Aṣṭurlābī, which must surely be by the same maker.[119]

The second celestial globe from the twelfth century was made in 539 H/AD 1144–1145 by Yūnus ibn al-Ḥusayn al-Aṣṭurlābī (No. 2 of the catalog). The globe is from the eastern part of the Islamic world and is made of two metal hemispheres joined more or less along what would be the course of the Milky Way, though the Milky Way is not designated on this globe

nor on any known Islamicate globe. It has engraved on it the 48 constellation figures and approximately 1025 stars, represented by inlaid silver dots that vary in size according to the magnitude of the star. The inscription on the globe states that the star catalog of Ptolemy was used for the coordinates of the stars after adding 15°18′ to correct the longitudes for the intervening time period. The stars are numbered within each constellation and 72 of the stars are named, as well as the 28 lunar mansions whose names are inscribed alongside the ecliptic. As is common, the meridian ring is missing and the horizon ring is a recent replacement. Nothing is known of this instrument maker and no other examples of his work have been identified, but he seems to have been a skilled craftsman and was probably a professional instrument maker, for he produced a precise globe as well as an attractive one, which from the iconography suggests a workshop in Persia, possibly Iṣfahān.

From early in the twelfth century, probably before AD 1120, and also from the eastern part of the Islamic world, we have a fascinating treatise on "The Sphere that Rotates by Itself" by ᶜAbd al-Raḥmān al-Khāzinī, who later dedicated some other astronomical writings to the Saljūq ruler of eastern Persia from 1097 to 1157, Sanjar ibn Malikshāh. This treatise, which has been recently edited and translated,[120] describes a celestial globe which, instead of being placed in the usual set of rings, is half sunk in a box and propelled so as to rotate once a day by a mechanism of pulleys driven by a weight resting on top a reservoir of sinking sand.

This sphere, which al-Khāzinī designed for someone named Abū al-Ḥusayn ᶜAlī ibn Muḥammad ibn ᶜĪsà and executed with the help of a carpenter (*najjār*) named ᶜAlī al-Sarakhsī, is set halfway into a box whose upper surface serves to mark the horizon. Over the sphere, along the north-south line, was affixed a half-circle of brass (*nuḥās*), which served as a meridian ring, with the axis of the globe set at the south pole inside the box and the north pole at a hole in the meridian ring corresponding to the geographical latitude of Marw. The rest of the box covered the top of the mechanism, which automatically rotated the sphere one rotation per day. The equator was inscribed on the globe and divided into 360 equal parts. Taking as a pole a point 23°35′ measured along the meridian ring from the pole of the equator, the ecliptic was inscribed and divided into zodiacal houses and degrees. Al-Khāzinī then indicated a circle on the surface of the box around the globe, which he also divided into 360°, and on which he named the four points of the compass, so as to serve as the horizon ring.

Al-Khāzinī furnishes no information as to the material out of which the sphere was fashioned nor the material from which he made a quadrant (*rubᶜ*). This quadrant, which he also called a *misṭarah* (rule), was equal to the quadrant of a great circle on the globe. Much of the treatise is devoted to using the "rule" and the globe in much the same ways that Qusṭà ibn Lūqā had earlier suggested for a celestial globe set in the customary rings (see Chapter 2 below). This rather ingenious conception of an automatically rotating celestial globe does not in fact appear to have been very practical because of the enormous size of the mechanism required and the difficulty of precisely regulating the movement. It does not seem to have influenced the development of celestial globes. There are, of course, many celestial globes extant that do not have rings, and it is always possible that some of them were mounted in something other than the usual meridian-horizon ring assembly. Consequently one cannot dismiss entirely the possibility that some globes were used in such an arrangement, although there is no corroborating evidence to suggest this for any extant globe.

From the thirteenth century several signed globes are preserved today. The earliest and in many ways the loveliest was made in AD 1225–1226 for a nephew of the great Saladin (Ṣalāḥ al-Dīn) in Egypt. The globe (No. 3) has the full set of 48 constellation figures engraved and damascened with copper, with approximately 1025 stars indicated by six different sizes of inlaid silver points corresponding to the various magnitudes. The globe also has a scale showing the

sizes of silver points used for the first five magnitudes. The inscriptions, which are in *naskhī* script rather than Kūfic script that would be more usual for this period, are damascened with silver or inlaid with silver wire. According to the inscription, the globe was made for al-Malik al-Kāmil, the Ayyūbid *sulṭān* of Egypt from AD 1218 to 1238, who had interests in irrigation works and other agricultural matters and, following the conclusion of the fifth crusade, corresponded with Emperor Frederick II of Sicily on scientific subjects.[121] The maker of the globe was (ᶜAlam al-Dīn) Qayṣar ibn Abī al-Qāsim ibn Musāfir al-Ashrafī al-Ḥanafī, who was born in upper Egypt in AD 1178–1179 and later resided in Syria, where he died in 1251 in Damascus. He was a renowned mathematician and architect,[122] and it is reported that the historian Qāḍī Jamāl al-Dīn ibn Waṣīl assisted Qayṣar in constructing another celestial globe of wood and gilt.[123]

The globe, made by Qayṣar in AD 1225–1226, is unusual in that the horizon ring and stand, which are probably the ones originally made for this globe, have incorporated into them two gnomons and graduated arcs making them elevation dials (see Chapter 2). The sphere itself is unusual in having Latin zodiacal names and Latin numerals engraved on it, but these may have been added later.

Another example of a thirteenth-century Islamicate globe comes from the famous school of metalwork that flourished in Mosul on the Tigris River north of Baghdād. The globe (No. 4) is made by Muḥammad ibn Hilāl al-Munajjim al-Mawṣilī (the astronomer of Mosul) in 674 H/AD 1275–1276. The globe is again made of two metal hemispheres with 48 engraved constellations and about 1025 stars indicated by inlaid silver points with the inscriptions in Kūfic script. Nothing is known of this maker except this one product, but judging by his name, he was an astonomer from Mosul who was probably trained in metalworking at the great center there. The globe is a handsome example of Islamicate metalwork as well as fine instrument-making, and compares favorably with other products of the Mosul school.[124]

An undated but signed globe of the later thirteenth century (No. 5) was constructed by Muḥammad ibn Muᵓayyad al-ᶜUrḍī, the son of the famous astronomer Muᵓayyad al-Dīn al-ᶜUrḍī al-Dimishqī, who made instruments for the observatory at Marāgha, about 50 miles south of Tabriz in Azerbaijan.[125] The observatory had been established by order of Hūlāgū Khān (the grandson of the founder of the Mongol Ilkhānid dynasty of Persia, Genghis Khān) under the direction of the astronomer Naṣīr al-Dīn al-Ṭūsī (born AD 1201).[126] The observatory was built outside of the city and the foundations remain visible today.

The globe was clearly made at the court of Hūlāgū Khān in Marāgha and may well have been, even though rather small, one of the several celestial globes no doubt used at the observatory, which continued to operate for a period even after the death of Hūlāgū in AD 1265. It is probably good evidence of the type of celestial globe carried from Persia, along with six other astronomical instruments, by Cha-ma-lu-ting (i.e., Jamāl al-Dīn) to Hūlāgū Khān's brother Kublay Khān, the first Yüan Emperor of China.[127] This particular undated globe, made of metal hemispheres, has 48 constellations and about 1025 stars indicated by inlaid silver points. The ecliptic latitude circles are damascened in silver at the zodiacal divisions, while the two circles forming the graduated band representing the equator are inlaid in gold wire. The names of the zodiacal signs are inlaid alternately in gold and silver; the script is Kūfic. The meridian, zenith, and horizon rings are probably original, and are unusual in that the horizon ring has no stand but rather a suspensory device by which it can be hung. The zenith ring appears to pivot about the sphere and to have a slit parallel to the face of the ring along the upper quadrants. It is possible that a needle-like gnomon was at one time inserted through this slit. The basic design of the rings is reminiscent of that described by al-Battānī in the ninth century, and in fact it is the only extant example of a ring assembly closely resembling that described by al-Battānī.

Another globe (No. 35) very similar in style to this globe by Muḥammad ibn Muᵓayyad al-ᶜUrḍī

is unsigned and undated. This very precisely executed globe, which unfortunately lacks the rings, was probably made about five years later possibly in Marāgha or Tabriz, and is a fine example of Ilkhānid metalwork.[128]

Further evidence of the widespread distribution of celestial globes in the thirteenth century is seen in the report[129] that when Hūlāgū Khān captured Alamūt (the mountain stronghold south of the Caspian Sea) in AD 1256, he found several astronomical instruments including a celestial globe with stand (*dhāt al-kursi*). From the western part of the Islamic world in the thirteenth century there comes a treatise on astronomical instruments by the Morrocan astronomer al-Marrākushī, which is an important source of information on the construction of celestial globes (see Chapter 2).

Another globe of the thirteenth century (No. 6) dated 684 H/AD 1285–1286 is slightly smaller even than the one made in Marāgha. It has the full set of constellation outlines and about 1024 stars. It is engraved in Kūfic script and bears the maker's name, Muḥammad ibn Maḥmūd al-Ṭabarī. Nothing is known about him, though the name suggests an origin in Ṭabaristān, a province in northern Persia on the southern shore of the Caspian Sea.

This globe presents some questionable or curious features. It is a hollow metal sphere having no visible seam and with two plugs (see Figure 6, where the plugs are marked with arrows), implying that it might have been cast by the lost wax method. This method is characteristic of Indo-Persian globes of a much later period (see Chapters 2 and 3). It is always possible that the technique for constructing globes in this manner was developed and perfected much earlier than the other remaining globes would lead one to suspect; and this particular globe was clearly made by a metalworker experienced and skilled in making seamless globes. The unusual features, however, make this supposition less likely than it would otherwise be. The Kūfic script on this globe is at times not very angular and tending towards *naskhī* (generally, but not without exception, characteristic of later products), as in forming the letters *ṣād*, *ḍād* and *ʿain*. The lines representing the celestial equator and ecliptic wobble slightly and the graduations are uneven. At the equinoxes the crossing of the equator and ecliptic are quite poorly executed compared with other globes, and in fact, some graduations are lacking. The stars themselves are so poorly positioned that in some instances it is difficult to align a given star on the globe with a star in illustrations and catalogs such as those given by al-Ṣūfī. On the basis of the stars near the ecliptic that can be identified, their positions when compared with well-made dated globes, indicate an epoch varying from the tenth to the sixteenth century. The stand and rings, which from the general appearance of the alloy, finish, and engraving appear to be contemporary with the globe, are graduated in a different scale than that used on the globe (an incongruous and unusual feature) and the directions in which the numbering runs on both the meridian and horizon rings are the opposite from those found on nearly every other extant set of rings. The horizon ring and stand seem to have been intended to serve as an elevation dial like those on the globe by Qayṣar in the thirteenth century. The gnomons, however, have not been properly aligned over the graduated arcs so that they cannot function; this misalignment could, of course, possibly be due to more recent incorrect repairs and restoration.

The globe has a second inscription stating that the stars were placed on it according to the *Book of the Constellations of the Fixed Stars* by al-Ṣūfī after increasing their longitude by five degrees (which gives an unusually low value for the rate of precession), followed by the interesting caveat "while the correction of whatever errors occur and the production of variant readings [is left] to those who are expert in language." It appears that the stars were actually placed on the globe after the constellations outlines were incised, and therefore that the coordinates from a star catalogue were not really used to determine the star positions despite the statement on the globe. Hence, one can conclude that while the globe was fashioned by a skillful metalworker, it was inscribed by someone who was apparently unfa-

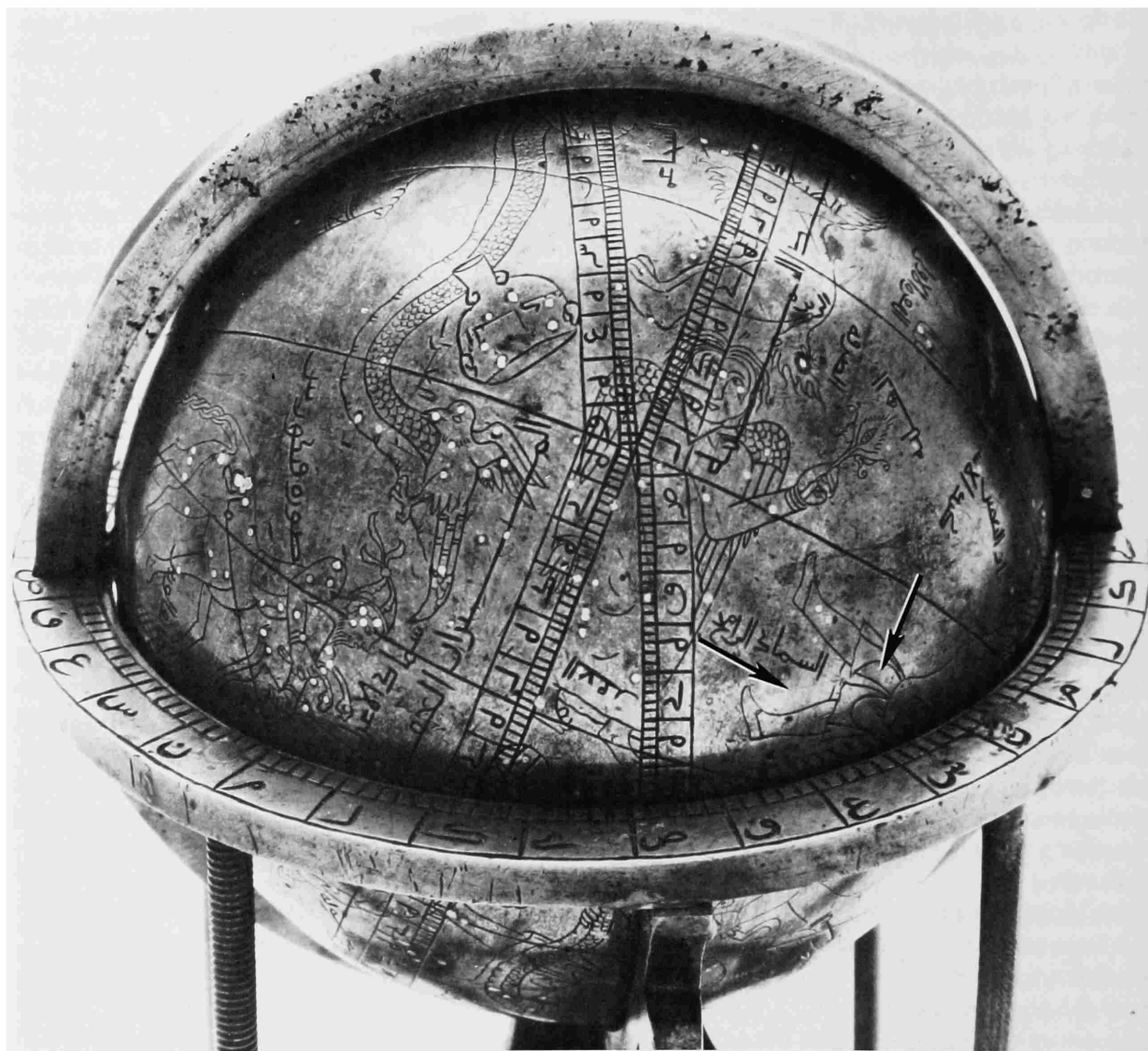



FIGURE 6.—Globe No. 6, dated 684 H/AD 1285–1286, by Muḥammad ibn Maḥmūd al-Ṭabarī. Musée du Louvre, Section Islamique. Arrows indicate plugs in holes resulting from casting process. (Photo: Courtesy of the Musée du Louvre)

miliar with the techniques for precisely executing the ecliptic and equator at the equinoxes, for holding steady the engraving of the great circles, for marking equal graduations, or techniques for accurately placing the stars on a globe.

The lack of precision evident on this globe indicates that it was not made by a professional instrument maker for the use of an astronomer, but was made by a skilled artisan for its artistic appeal. It is curious, however, that the maker, even specifying in the second inscription on the globe that he was the engraver and hence not just the caster of the globe, would sign himself as *al-Asṭurlābī* (an astrolabe maker), when he did not make an astronomically correct instrument. Such cases of imprecision resulting in a technically inaccurate and non-functional globe present the possibility that it is a much later attempt by

an artisan to copy an earlier thirteenth-century globe for sale to someone interested in the artistic merit rather than the actual use of the globe. In addition, the fact that someone has signed and dated a non-functional globe—even though an attractive one—perhaps is further evidence that it is a relatively recent intentional reproduction of a thirteenth-century globe rather than simply a globe produced in the thirteenth century by a metalworker who did not know how to make accurate celestial globes but did know the complicated process for casting seamless ones. On the other hand, it might be concluded from ᶜAbd al-Raḥmān al-Ṣūfī's statement about "decorated celestial globes" that there is a long tradition going back to at least the ninth century AD in the Islamic world of producing quite inaccurate celestial globes.

Many of the criticisms made of the globe by al-Ṭabarī can also be made of the globe that, by its date, is the next oldest extant globe (No. 60). This globe (see Figure 7) is also a hollow metal globe with no observable seam, several plugs visible, and no seam detectable by probing the

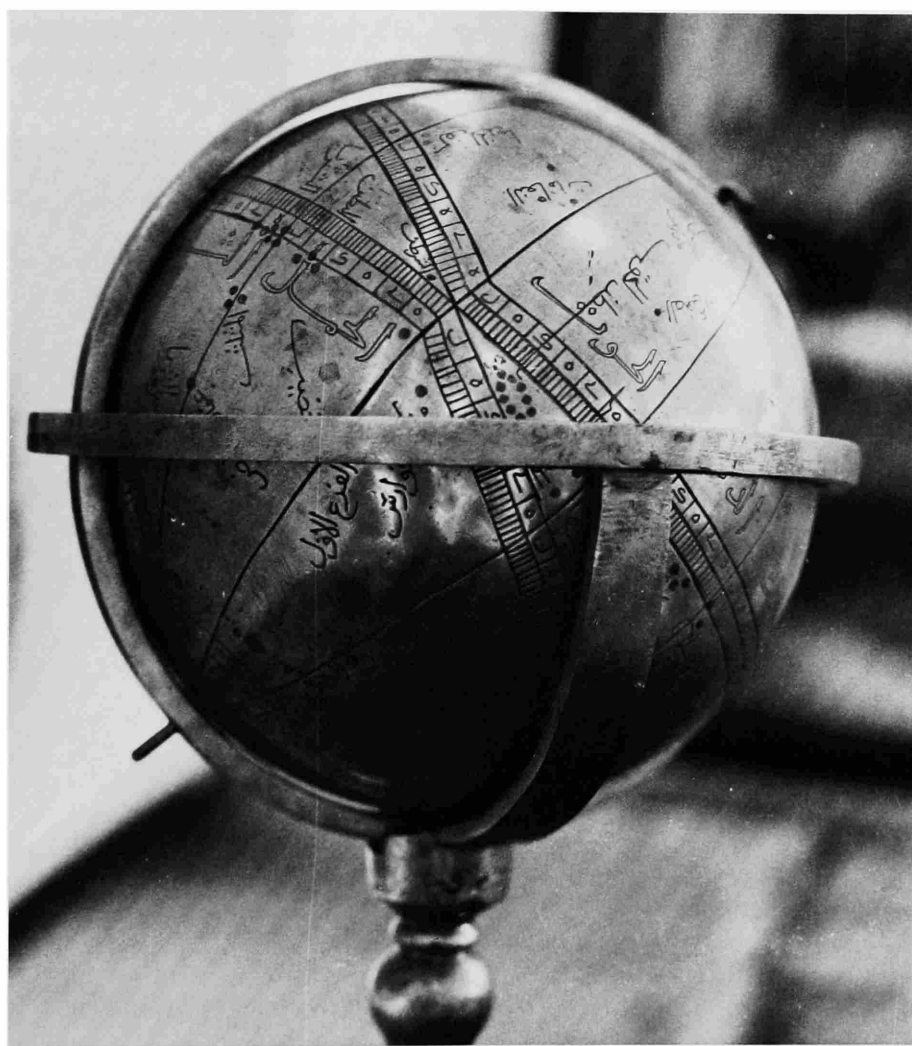



FIGURE 7.—Globe No. 60, dated 718 H/AD 1318–1319, by ᶜAbd al-Raḥmān ibn Burhān al-Mawṣilī. Oxford, Museum of the History of Science. (Photo: M.B. Smith)

interior surface. It is therefore likely to have also been cast by the *cire perdue* process. The globe has only about 100 stars indicated by inlaid silver points, and has no constellation outlines. The sometimes poorly executed script is *naskhī*, which is unusual for globes prior to the sixteenth century.

One inscription on the globe reads: "the work of ᶜAbd al-Raḥmān ibn Burhān al-Mawṣilī in the months [*sic*] of the year seven hundred and eighteen [AD 1318–1319]." A second inscription is somewhat obscure, but seems to read, "Undertaken at the instigation of the poor, the weak Ghiyāth known as al-Manṣūr in the months of the year [lacuna] and seven hundred." The dates in both these inscriptions are written out in words, which is extremely unusual. A third inscription appears to read "By order of the treasuries of the Sulṭān al-Maṭṭ ["the proud," which with some modification could be read as *al-malik* "the ruler"] al-ᶜĀdil Ulugh Bēg." If the date given by the maker Ibn Burḥān of Mosul is considered correct, then the last inscription must have been added later, for Ulugh Bēg founded the observatory at Samarqand in the fifteenth century, not fourteenth. All three inscriptions are quite similar in style and appearance, however, and do not give the immediate impression of having been done by different engravers (see Figure 8).

All the great circles on the globe are somewhat wavy, the graduations uneven, and the crossing

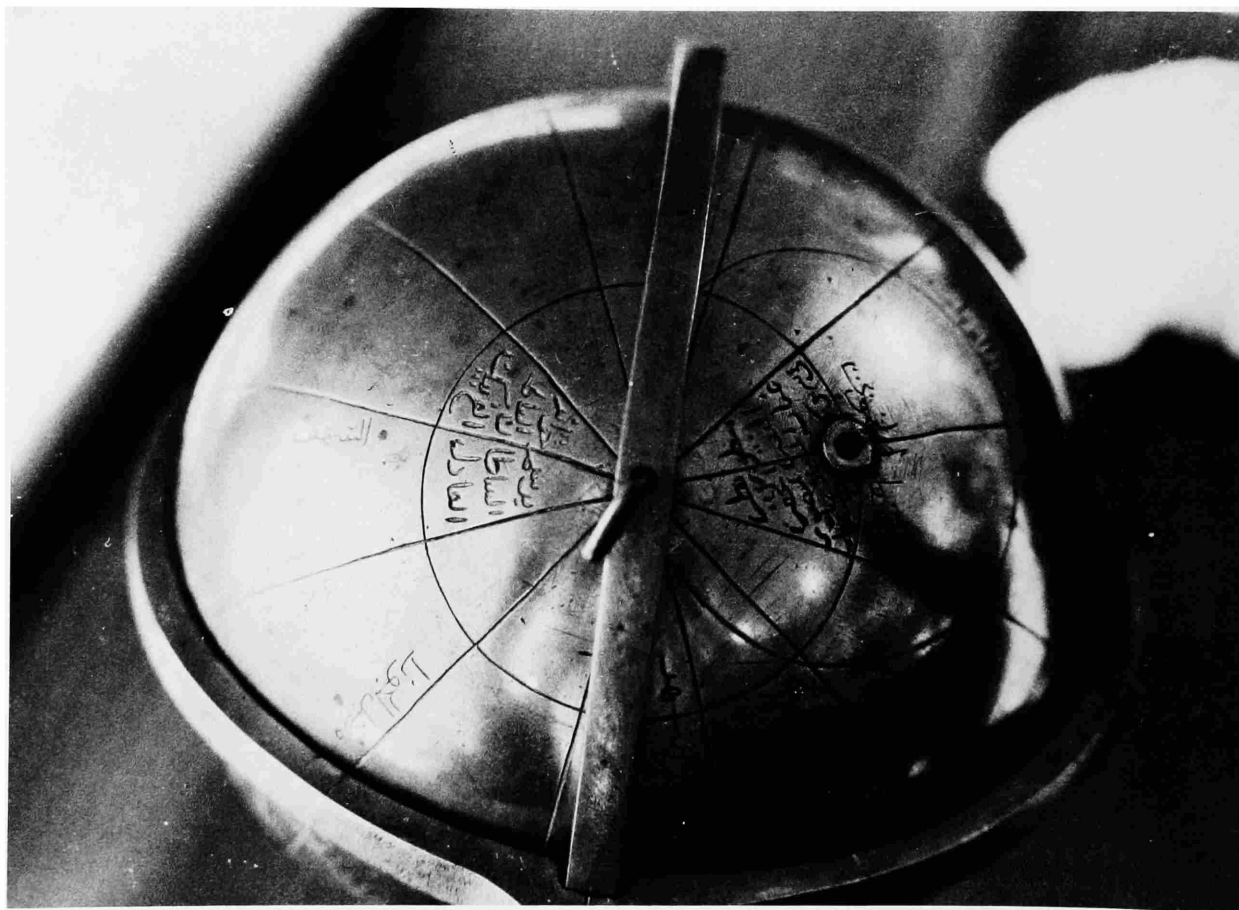



FIGURE 8.—Detail of inscriptions on globe No. 60, dated 718 H/AD 1318–1319, by ᶜAbd al-Raḥmān ibn Burhān al-Mawṣilī. Oxford, Museum of the History of Science. (Photo: M.B. Smith)

at the equinoxes poorly executed. The globe also has the lunar mansions along the ecliptic indicated by patterns of dots that are not to be found in the strictly astronomical literature, such as the writings of al-Ṣūfī or al-Bīrūnī, but rather in treatises such as the *Marvels of Things Created and Miraculous Aspects of Things Existing* written by al-Qazwīnī in the thirteenth century and in writings concerned with lunar mansions and pre-Islamic poetry and calendars (see section on Lunar Mansions, Chapter 5). These patterns of dots representing the lunar mansions are a unique feature among extant Islamicate globes and represent a different tradition used by the maker. The word for "the work of" (*ᶜamal*) used in the signature occurs on only one other globe before the seventeenth century, and both globes are inaccurate and non-functional. The pattern for graduating the equator is nearly unique and is not as useful as the common pattern.

The evidence of the circles, graduations, and star positions and the conflict inherent in the inscriptions make rather dubious the authenticity of this globe as an example of early fourteenth-century globe making. In any case it was certainly not made by or for an astronomer (and Ulugh Bēg, for whom it was supposedly made, was very well versed in astronomy). It is inaccurate and of value only as an example of artistic metalwork and not as a functioning celestial globe.

The fourteenth and fifteenth centuries saw one workshop of instrument makers who produced four celestial globes still preserved today. In Kirmān in southeast Persia a well-known astrolabe maker Jaᶜfar ibn ᶜUmar ibn Dawlatshāh al-Kirmānī made two celestial globes, one in 764 H/AD 1362–1363 (No. 7 of the catalog; see Figure 9), and one in 785 H/AD 1383–1384 (No. 8

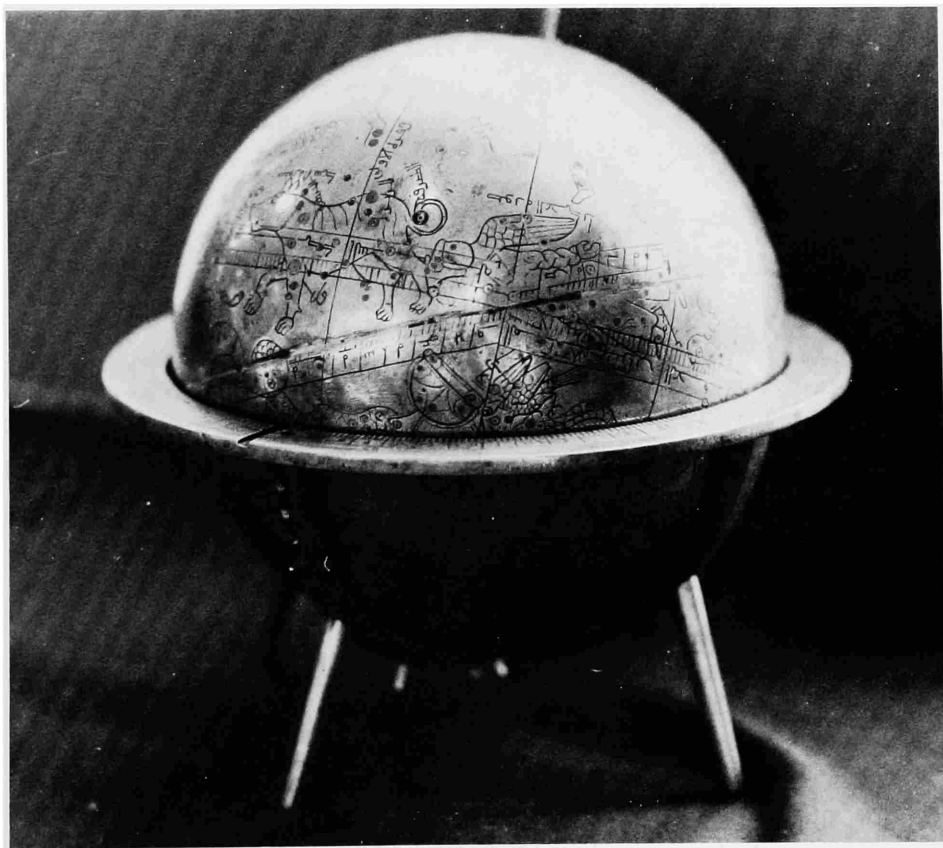



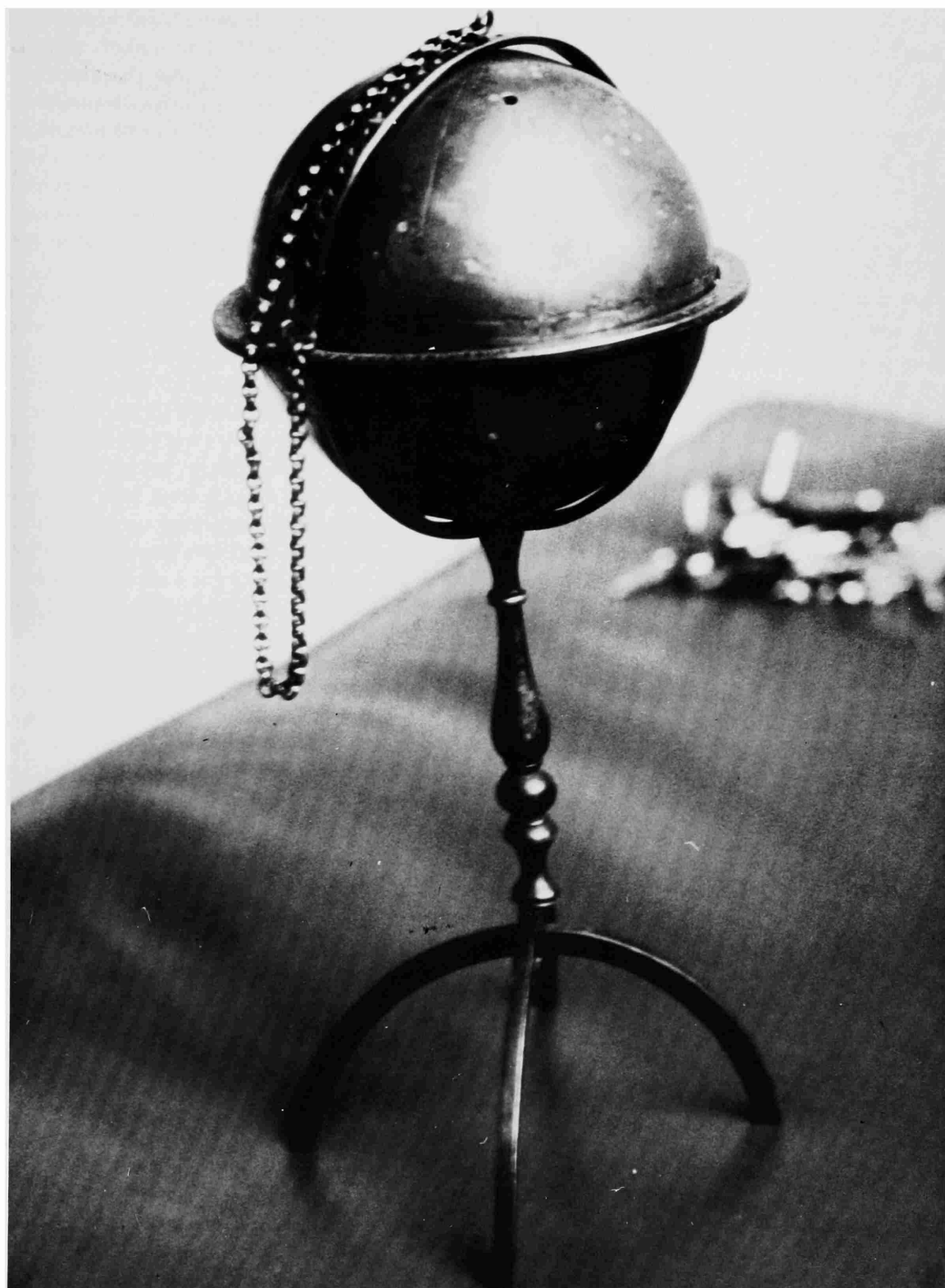
FIGURE 9.—Globe No. 7, dated 764 H/AD 1362–1363, by Jaᶜfar ibn ᶜUmar ibn Dawlatshāh al-Kirmānī. Oxford, Museum of the History of Science. (Photo: M.B. Smith)

of the catalog). Both globes are made of metal hemispheres and have the full set of consetallation figures engraved with approximately 1024 stars. Both are engraved in Kūfic script and bear inscriptions stating that the star positions were taken from the *Book of Constellations* by Abū al-Ḥusayn ᶜAbd al-Rahmān al-Ṣūfī, with an increase in the longitude of 6°3′ for the earlier globe. The later globe has a lacuna in the inscription where the minutes are given, but using the same value he used earlier (and which his son used later), there would be an increase of 6°23′ on the second globe. On the earlier globe the inscription giving the maker is engraved over an earlier one saying that Jaᶜfar had made it for a certain Muḥammad ibn Aṣīl, but for unknown reasons the maker attempted to obliterate the name of this patron. This Jaᶜfar ibn ᶜUmar is also known from four astrolabes made between AD 1354 and 1388.[130]

Muḥammad, the son of Jaᶜfar, was also an instrument maker who is known to have made two celestial globes and two astrolabes[131] that are preserved today. Both globes by the son are of the style having only major or astrolabe stars and no constellation outlines and are made of metal hemispheres. One globe, made in 813 H/AD 1410–1411 is signed simply Muḥammad ibn Jaᶜfar al-Aṣṭurlābī (No. 61). The other globe (No. 62; see Figure 10) is dated 834 H/AD 1430–1431, and signed Muḥammad ibn Jaᶜfar ibn ᶜUmar al-Aṣṭurlābī, known as (*al-mulaqqab*) Ḥilāl. Some have read the last name as Jalāl rather than Ḥilāl. The original rings and stand are still preserved with the latter globe. The father's globes are precisely made, clearly executed in the tradition of a professional scientific instrument maker. The son's globes, on the other hand, tend not to be as accurately inscribed as those by his father, with slight wobbles in the great circles and some irregularity in the graduation. The latter globes display a certain carelessness in execution, but are by no means as technically inaccurate and non-functional as many of the extant globes, such as the two previously mentioned.

About the same time that Muḥammad ibn Jaᶜfar was producing instruments in Kirmān, an observatory was flourishing at Samarqand to the northeast in Transoxiana. The observatory had been founded by Ulugh Bēg ibn Shāh-Rukh[132] in AD 1420, where a staff of astronomers headed by Jamshīd Ghiyāth al-Dīn al-Kāshī carried out observations and compiled astronomical tables and a star catalog titled *Zīj-i Sulṭānī* (AD 1440). This star catalog,[133] which was essentially that of al-Ṣūfī with improvements in the coordinates, was an important source for star positions for subsequent globe makers in the eastern part of the Islamic world. In a letter to his father Ghiyāth al-Dīn al-Kāshī described several of the instruments at the observatory, in the course of which he made an indirect reference to a celestial globe.[134]

The sixteenth century is represented by only two globes, both of them hollow metal globes that appear to have no seam but show plugs that are probably from the lost wax casting process. The earliest of the two is, unfortunately, an inaccurate and non-functional globe (No. 9). The inscription giving the maker has been marred by a large rectangular hole and a plug of lead, but informs us that the maker was one Jamāl al-Dīn Muḥammad [ibn] . . . al-Dīn Muḥammad, who says he was a Hāshimid[135] by ancestry (*al-Hāshimī nasaban*) and a Meccan by birth (*al-Makkī mawlidan*). The date is given as 981 H and Yazdijird 952 (AD 1573–1574). Despite the fact that the maker specifies that he was born in Mecca and a member of the Hāshimid family, which ruled Mecca from the tenth century to the first part of the present century, it is unlikely that the globe was made in Arabia. There is no further evidence that seamless metal globes were ever made other than in the eastern part of the Islamic world and the date is given in the Yazdijird era, which is a Persian calendar of Sassanian origin and unlikely to have been used in Arabia even in the sixteenth century under Ottoman rule.

FIGURE 10.—Globe No. 62, dated 834 H/AD 1430–1431, by Muḥammad ibn Jaᶜfar ibn ᶜUmar al-Aṣṭurlābī. London, British Museum, Department of Oriental Antiquities. (Photo: M.B. Smith)

Nothing is known of the maker, nor are any other examples of his work known. The globe itself has poorly drawn constellation figures with disproportionately large stars added after the constellation outlines were engraved and very inaccurately positioned. The graduations are very irregular and there are no holes at the celestial poles, which would be necessary for it to function properly. The maker has also used the word *ʿamal* for "the work of" in the signature, which does not occur before the seventeenth century except on globe No. 60 (mentioned above), which is also non-functional and has many questionable features. The imprecise nature of this design suggests that the maker was not a professional instrument maker, but rather a metal worker desiring to produce an object of decorative appeal but not one of use to an astronomer.

It is most unfortunate that the three earliest extant examples of hollow seamless metal globes (Nos. 6, 9, and 60) should all be of such an inaccurate and non-functional form with dubious characteristics about them, produced by metalworkers who are otherwise unknown. As with all such globes, they give rise to speculation that they might be later attempts by metalworkers who were not professional instrument makers to make a reproduction of an older celestial globe for a market that does not require technical accuracy and would not recognize errors or inconsistencies. Such assertions cannot be definitely substantiated, however, and it is always possible that in the thirteenth, fourteenth, and fifteenth centuries there was also a market for technically inaccurate but artistically pleasing celestial globes.

When we turn to the second globe of the sixteenth century (No. 10, illustrated in Figures 11 and 69) we see a very fine example of a hollow metal seamless globe produced, judging from the maker's name and the basic style of the globe, in Kashmīr in the western Himālayas in northern India. The globe was made by ʿAlī Kashmīrī ibn Lūqmān and is dated 998 H, the thirty-fourth year of the reign of the Mughal Emperor Akbar, which is equivalent to AD 1589–1590. The globe was made just one year after Akbar entered the valley and Kashmīr became a *ṣūba* (province) of the Mughal Empire.[136] The maker, who is not known by any other work, adds that he made the globe as an *aide-mémoire* to astrolabe makers. The globe is a well-constructed piece of metalwork as well as precisely executed instrument, with constellation outlines depicted in a style typical of early Mughal art. While the present owner did not permit examination of the globe, it can be asserted with some certainty, based on the available photographs, that the globe is a seamless, probably cast, globe. Some of the plugs (probably from the casting process) are indicated by arrows in Figure 11. Consequently, we can be fairly certain that the complicated technique for making seamless metal globes was well established in northwestern India by the last quarter of the sixteenth century. (See Chapter 2 for a discussion of the method of constructing such a globe.)

In the sixteenth and seventeenth centuries in northwest India a family at Lahore maintained a remarkable workshop that, through four generations, produced numerous well-made scientific instruments, in particular planispheric astrolabes and celestial globes. Lahore, on the upper course of the Indus river, was the capital of a Mughal province or *ṣūba* of the same name, later called the Punjāb. The activity of these metalworkers covered the reigns of the second through the ninth Mughal rulers of India, who spoke the vernacular Turki but maintained Persian as the official language of the court.

This particular family of metalworkers from Lahore excelled in certain metallurgical techniques, in particular the production of hollow cast globes. The variety in the techniques and designs of the engraved images on these globes suggests that the family maintained a workshop of metalworkers and apprentices, in which several people would perhaps be involved in the production of an instrument which nevertheless bore only the name of the family member supervising that production.

The earliest extant instrument by this family is an astrolabe made in 975 H/AD 1567–1568 by the apparent founder of the workshop, Allāhdād.

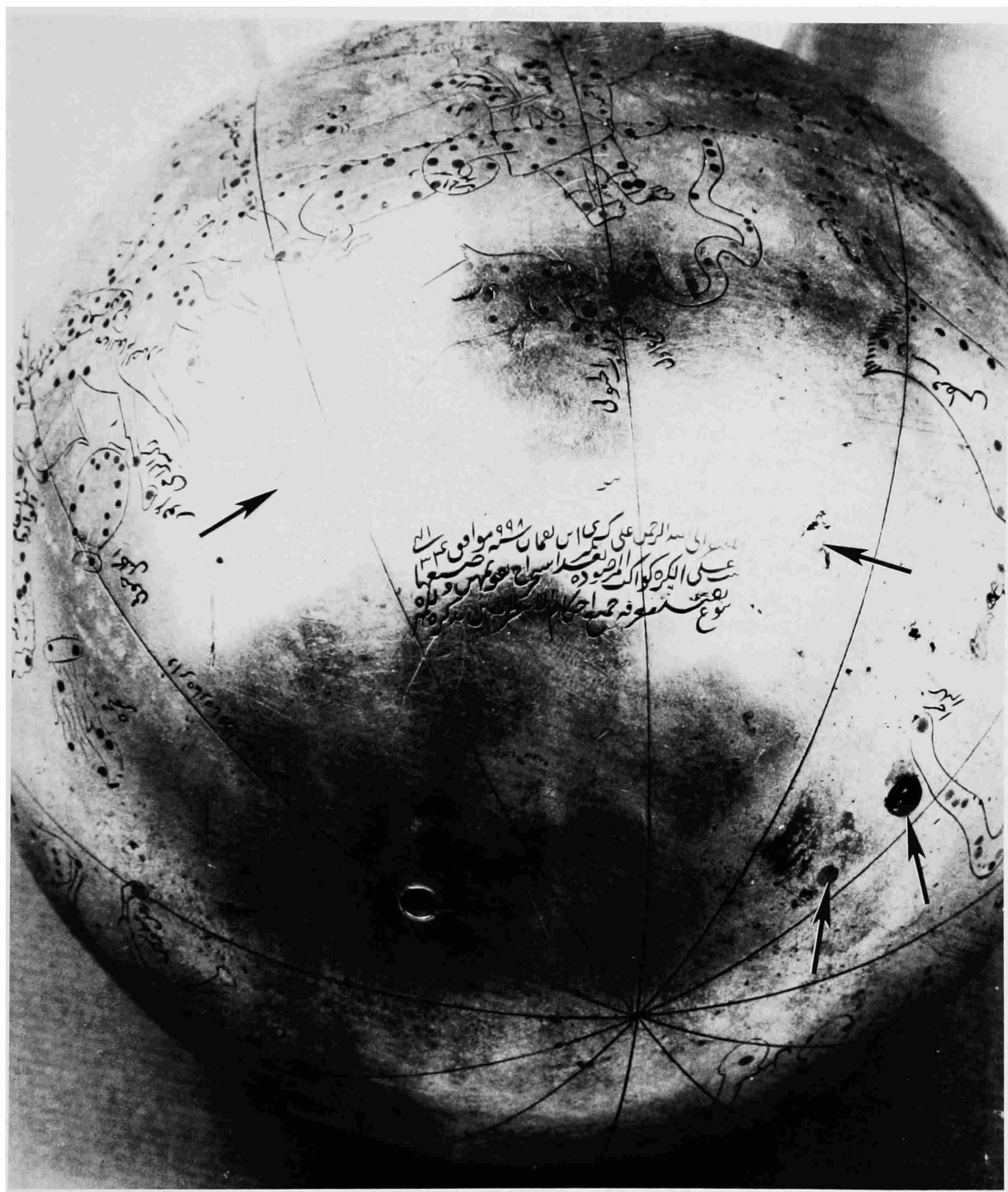



FIGURE 11.—Detail showing signature of maker on globe No. 10, dated 998 H/AD 1589–1590, by ʿAlī Kashmīrī ibn Lūqmān. London, Private Collection. Arrows indicate plugs. (Photo: Alain Brieux)

He called himself simply Ustādh Allāhdād Asṭurlābī Lāhūrī, that is, Master-craftsman Allāhdād, the Astrolabist from Lahore. Three extant astrolabes were made by him, only one of which is dated.[137] The name Allāhdād is a compound of *Allāh* (God) and *dād* (gift).[138] It is only from other members of the family—his grandsons and great-grandsons—that further information about Allāhdād can be gathered. In the name as it is written by later family members, Shaykh Allāhdād Asṭurlābī Humāyūnī Lāhūrī, it is likely that Humāyūnī was intended to indicate the fact that the founder of the workshop had lived at the time of Humāyūn,[139] who ruled India from 1530 to 1556 as the son and successor of Bābur, the Tīmūrid conqueror who had come from Kābul in the Afghan mountains into the Indus plain to found the Mughal dynasty in India.

There is a possibility, however, that Allāhdād was also an instrument maker at the court of Humāyūn and that the *nisbah* (the name usually derived from the place of origin or trade) was intended here to be an honorific indicating royal patronage, though no mention is made of him in the records of Humāyūn's reign. If Allāhdād was an astrolabist at the court of Humāyūn he must have been quite young, for his son was flourishing as a craftsman 52 years after the death of Humāyūn, and his grandsons were productive in the second quarter and middle of the seventeenth century.

Humāyūn's interest in astronomy and astrology was well-known. In the *Akbarnāma*[140] written by Abū al-Faḍl, minister to his son and successor, he was mentioned as having "an extraordinary interest and proficiency in the astrolabe, the celestial globe (*kurah*), and other instruments of the observatory." His grandson, Jahāngīr, mentions in his memoirs[141] that he was presented "with a compendium in the handwriting of the late king Humāyūn . . . containing some prayers, an introduction to the science of astronomy, and other marvelous things, most of which he had studied and carried into practice." Humāyūn was also responsible for attracting from Persia various artisans with whom he had become familiar during his temporary exile in Persia following his defeat by his brother Sher Khān, after which he was able to regain control only with the aid of Shāh Ṭahmāsp, the Ṣafavid ruler of Persia, himself a patron of the arts. The resulting blending in northwest India of the skills and styles of Persian artists with those of native Indians subsequently trained by these Persian artisans resulted in a style commonly referred to as Indo-Persian.

The one dated instrument bearing the name of Allāhdād was made during the reign of the successor to Humāyūn, Akbar, who ruled from AD 1556–1605. Akbar had moved the Mughal court to Lahore, and by 1596 the empire was consolidated and the borders set to include an area from the Arabian Sea to the Bay of Bengal and from the Himālayas to the Narbada river, as well as the Kābul province (Afghanistan) west of the Indus. Akbar also entertained European contacts at his court through the Jesuit missions and embassies sent for promoting trading interests.

The son of Allāhdād, Mullā ʿĪsà ibn Allāhdād, also worked during the reign of Akbar. The five extant astrolabes under his name date from AD 1600 to 1604.[142] There are no celestial globes known to have been made by him.

ʿĪsà ibn Allāhdād had two sons who were also instrument makers: Muḥammad Muqīm and Qāʾim Muḥammad. The two brothers signed two astrolabes as co-makers. One is dated 1017 H/AD 1609; the other is estimated to be made about 1635.[143] Muḥammad Muqīm produced under his name alone 33 instruments, of which fourteen astrolabes can be dated between AD 1624 and 1660.[144] He is known to have made one celestial globe (No. 15), dated 1049 H/AD 1639–1640, which appears to be a seamless metal globe with plugs.

His brother Qāʾim Muḥammad signed two astrolabes,[145] in addition to the two on which the two brothers collaborated, and four celestial globes. The earliest globe (No. 11 of the catalog) was constructed for a certain Nawāb Iʿtiqād Khān in 1032 H/AD 1622–1623 (the eighteenth year of the reign of Jahāngīr, who ruled from 1605 to 1626; see Figures 12 and 13). The memoirs of Jahāngīr mention two men by the

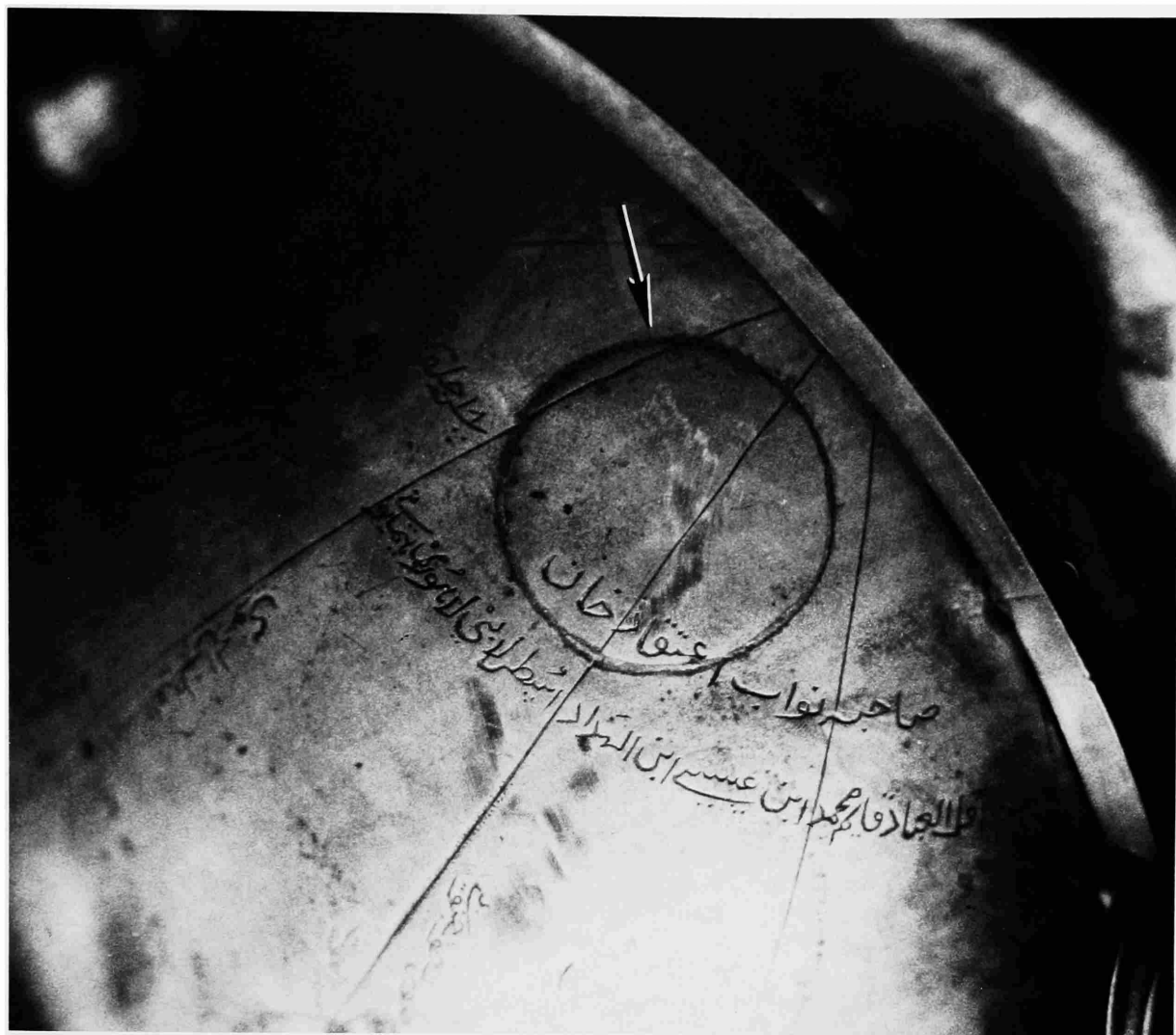



FIGURE 12.—Detail showing signature of maker, globe No. 11, dated eighteenth year of the reign of Jahāngīr (AD 1622–1623), by Qā'im Muḥammad ibn ʿĪsà ibn Allāhdād Asṭurlābī Lāhūrī Humāyūnī. Lancashire, Stonyhurst College. Arrow indicates plug. (Photo: M.B. Smith)

name of Iʿtiqād Khān, either one of whom might have been the patron requesting the celestial globe. One was given the title of Āṣaf Khān and was the brother of Nūr Jahān, the wife of Jahāngīr, and a leading figure at the court.[146] The other was a younger brother who was known originally as Shāpūr and during the eighteenth year of Jahāngīr's reign was the governor of Kashmīr, at that time part of the Mughal province of Kābul.[147] Unfortunately, however, there is no mention of this family of instrument makers in the memoirs of Jahāngīr or in any other written source from Mughal India—an omission which tends to indicate that the name Humāyūnī was used to indicate contemporaneity of Allāhdād with Humāyūn, and that even if the founder of the workshop had enjoyed royal favor, his descendants probably did not.[148] While perhaps not actually enjoying royal favor, any good artisan in the city where the court was located would have an adequate supply of wealthy customers among the retainers.

FIGURE 13.—Detail showing Virgo. Globe No. 11, dated eighteenth year of the reign of Jahāngīr (AD 1622–1623), by Qā᾿im Muḥammad of the Lahore workshop. Lancashire, Stonyhurst College. (Photo: M.B. Smith)

Of the other three celestial globes by Qā᾿im Muḥammad (Nos. 12, 13, and 14) the first two were made in the twenty-first and twenty-second years of the reign of Jahāngīr (AD 1625–1626 and 1626–1627), while the third was produced in 1047 H/AD 1637–1638. This was during the sumptuous rule of Shāh Jahān, who built the lovely sepulchre for his wife Mumtāz Mahal in Agra, known as the Tāj Mahal. (For illustrations of the first two globes see Figures 36, 38, and 42.) On the latter globe Qā᾿im Muḥammad supplied in a Persian inscription some information on the design of the globe, saying that 1022 stars in 48 constellations were placed on it based upon the positions determined at the observatory of Ulugh Bēg and that three degrees were added to their celestial longitudes so as to have the positions correspond to the date 1047 H. It is also likely, for reasons which are explained in Chapters 3 and 4 of this study, that the anonymous globe now at the Smithsonian Institution which forms the focus of the study, may also be attributed to Qā᾿im Muḥammad ibn ᶜĪsà ibn Allāhdād Aṣṭurlābī Lāhūrī Humāyūnī. All of the globes made by Qā᾿im Muḥammad have a full set of stars and the 48 constellation outlines. It is likely that the catalog of Ulugh Bēg was used as a source for the star positions not only for the globe made in AD 1637–1638 but also for all the globes of the Lahore workshop.

Qā᾿im Muḥammad and Muḥammad Muqīm both had sons who continued the workshop for a fourth generation. Muḥammad Muqīm had two sons, Jamāl al-Dīn and Ḥāmid. Only three instruments are known to be made by Jamāl al-Dīn, all of them astrolabes dating from 1681 to 1692 during the reign of Aurangzīb ᶜĀlamgīr I.[149]

Ḥāmid attempted one celestial globe that we know of (No. 68) dated 21 Shawwāl 1065 (24 August AD 1655), in addition to seven extant astrolabes ranging from AD 1628 to 1691, spanning the reigns of Shāh Jahān (AD 1628–1657), Murād Bakhsh and Shāh Shujāᶜ (who both ruled in AD 1657), and Aurangzīb ᶜAlamgīr I (AD 1658–1707).[150] An eighth astrolabe made in approximately AD 1654 bears the signature of both Ḥāmid and his cousin Ḍiyā᾿ al-Dīn Muḥammad.[151] The only globe known to be made by Ḥāmid (see Figure 14) is the type of globe having only the major or astrolabe stars, in this case 67, and no constellation outlines. It too appears to be a seamless cast globe.

Ḍiyā᾿ al-Dīn Muḥammad was the son of Qā᾿im Muḥammad and clearly the most prolific producer of instruments from this workshop. His instruments exhibit great variety in the quality of workmanship, as might be expected from such a large number. The range cannot be explained in terms of the evolution of a technique, but is probably due to the various assistants involved in their production. Yet certain artistic and technical features characterize and differentiate the products of Qā᾿im Muḥammad and his son Ḍiyā᾿ al-Dīn Muḥammad and their respective assistants. In Chapter 4 Andrea Belloli discusses the

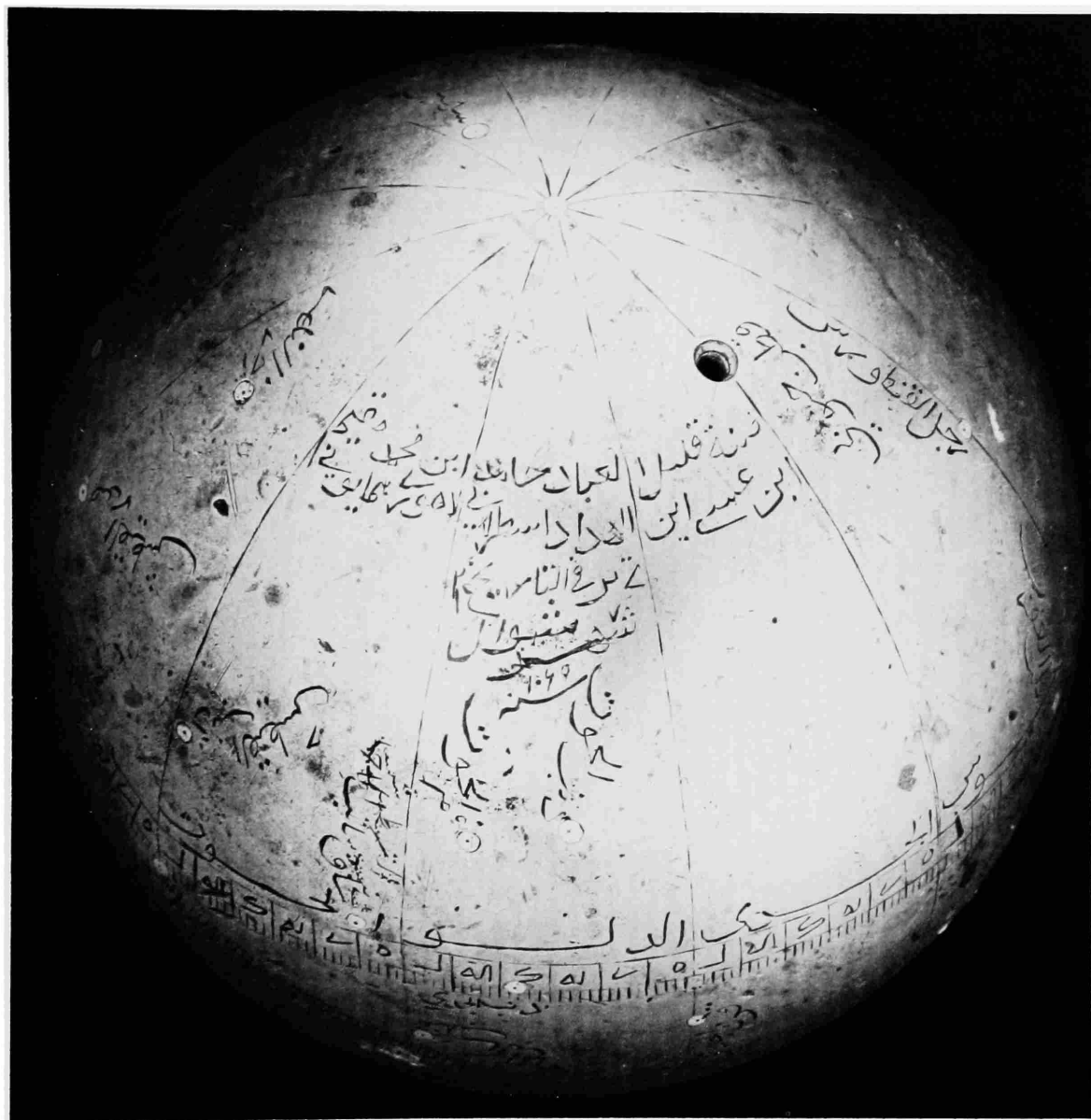



FIGURE 14.—Detail showing signature of maker. Globe No. 68, dated 21 Shawwāl 1065 H/AD 1665 by Ḥāmid ibn Muḥammad Muqīm ibn ʿĪsà ibn Allāhdād Asṭurlābī Lāhūrī Humāyūnī. Cambridge, Whipple Museum of the History of Science. (Photo: Whipple Museum of the History of Science)

artistic aspects of their celestial globes, while the distinguishing features of their designs from the astronomical standpoint are treated in Chapter 3.

Ḍiyāʾ al-Dīn Muḥammad produced the largest number of Islamicate celestial globes attributable to any single maker, and the production of these globes was spread fairly evenly over his working life, which was at least 44 years. In addition to the astrolabe made in collaboration with his cousin Ḥāmid, 25 astrolabes are signed by Ḍiyāʾ al-Dīn Muḥammad, of which 20 are dated from AD

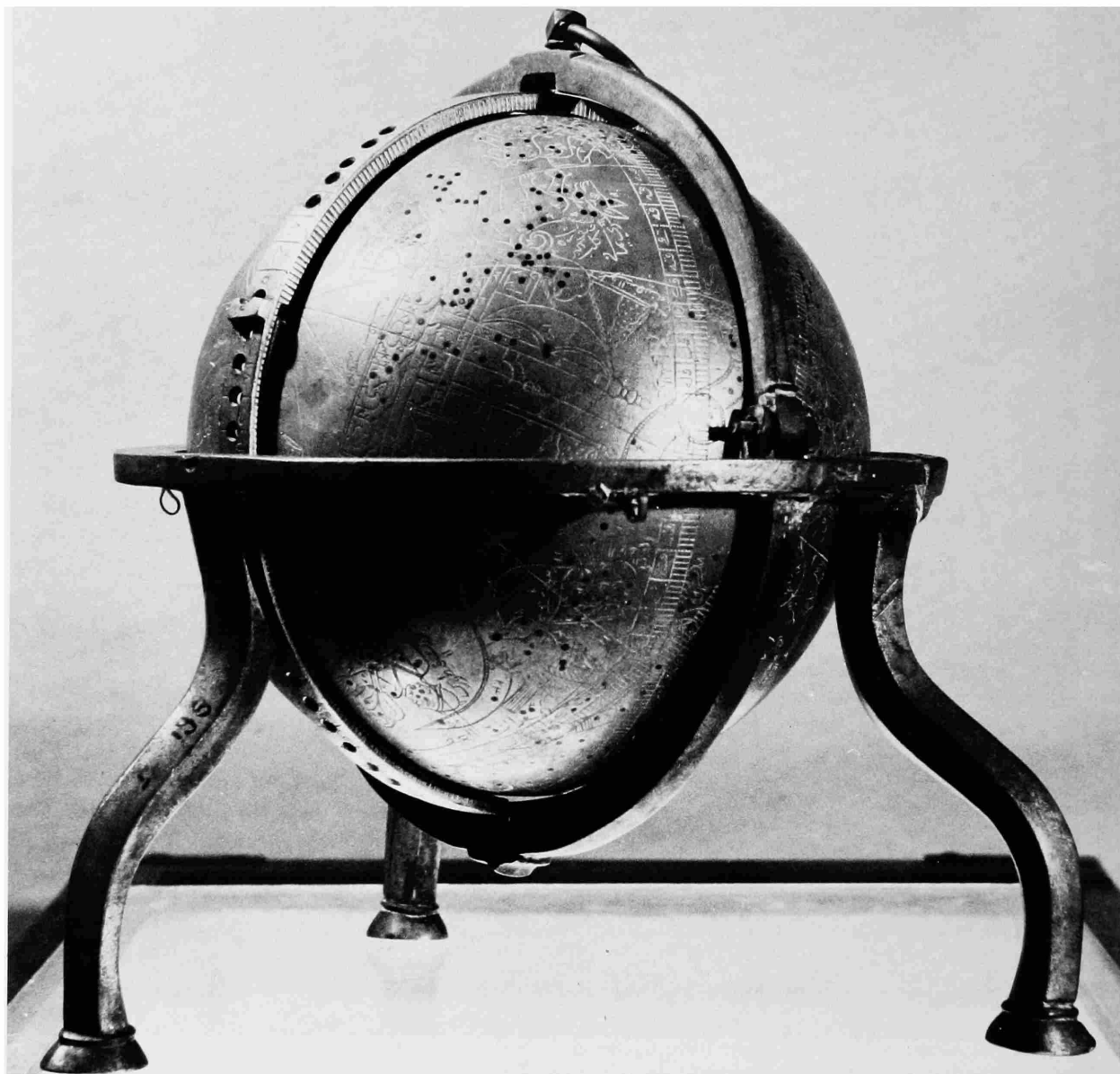



FIGURE 15.—Globe No. 18, dated 1055 H/AD 1645–1646, by Ḍiyāʾ al-Dīn Muḥammad of the Lahore workshop. The meridian ring is not properly mounted. Columbia University, David Eugene Smith Collection. (Photo: Columbia University)

1637 to 1680, from the reigns of Shāh Jahān to that of Aurangzīb ʿĀlamgīr.[152] The 15 celestial globes (with a single exception they are hollow seamless globes cast by the *cire perdue* process) date from 1645 to 1680 (Nos. 18–24, 26–28, 30, 66, 69, and 71 of the catalog; see Figures 15 and 16). Eleven of the globes have the 48 constellation figures with approximately 1018 stars

FIGURE 16.—Globe No. 27, dated 1074 H/AD 1663–1664, by Ḍiyāʾ al-Dīn Muḥammad of the Lahore workshop. Royal Scottish Museum, Department of Technology. (Photo: Royal Scottish Museum)

indicated, while three have no constellation outlines and only major stars indicated.

The one celestial globe signed by Ḍiyāʾ al-Dīn Muḥammad that is not a seamless globe (No. 30) is in fact not really a globe, but an open, cut-out sphere consisting of two raised or hammered hemispheres, in which the spaces between the constellations and the great circles have been cut out, or worked *à jour*. The stars are indicated by holes perforating the sphere, some of which seem to be filled with glass or mica. The metal hemispheres, which have been covered with gilt paint and varnish, are easily separated and meet along the line of the equator (see Figure 17). The inscription on the sphere states that it was made at the order of the Mughal ruler Aurangzīb

FIGURE 17.—Globe No. 30, dated 1090 H/AD 1679–1680, by Ḍiyāʾ al-Dīn Muḥammad of the Lahore workshop. Paris, Private Collection. (Photo: Alain Brieux)

ᶜĀlamgīr, and calls the sphere *kurah ikhtirāᶜī arḍwī samāʾī* (a specially invented terrestrial-celestial sphere). This statement implies that since it was both a terrestrial and celestial sphere, there was once a small terrestrial globe placed in it. By having the stars as well as the spaces between the constellations and circles cut out, sufficient light could enter the sphere to allow inspection of the enclosed terrestrial globe. Thus this sphere, especially designed for the Mughal ruler ᶜĀlamgīr I, the third son of Shāh Jahān, seems to have been part of a tradition of demonstrational armillary spheres. It is of unique design among extant Islamicate instruments, for no other armillary spheres are extant. Armillary spheres are seldom illustrated or mentioned in Islamicate astronomical literature, and when they are, except where there was European influence, they are nearly all *observational* armillary spheres in the Ptolemaic tradition rather than *demonstrational* armillary spheres as this sphere would have been.[153]

The last instrument known to have been executed by Ḍiyāʾ al-Dīn Muḥammad is a type of astrolabe called a *ṣafīḥah zarqalīyah*, different from the conventional planispheric kind.[154] It is dated the twenty-second year of the reign of Aurangzīb ᶜĀlamgīr (AD 1680), and according to the inscription it was made at Delhi for Nawāb Iftikār Khān who was fawjdār (a police official) at Jawnpūr, a city on the Ganges River in the state of Allāhabad (later Oudh). This patron is possibly Sulṭān Ḥusayn, who was given the title Iftikār Khān in the first year of the reign of Aurangzīb ᶜĀlamgīr and ruled Jawnpūr at the time the instrument was made. This large astrolabe had a diameter of 610 mm and was later placed at the Jaipūr Observatory built by Jai Singh in AD 1734. The fact that this last item is stated to have been made in Delhi and the celestial-terrestrial sphere made at just about the same time was executed for the Mughal emperor himself, suggests that the workshop of the family had by that time moved to Delhi, the seat of the Mughal court since AD 1648.

This family of Mughal craftsmen from the Punjāb of northwest India (modern Pakistan) were clearly the most important producers of hollow metal seamless globes. It is evident that the Lahore family must have prided themselves on their ability to produce a globe by such a technique, for using the lost wax method would involve long hours of tedious work, both in cleaning out the inner mold and carefully plugging the holes caused by the cooling process (see Chapters 2 and 3). Of course assistants were employed for much of the tedious work. A globe in hemispheres could be made in a small fraction of the time required to cast one by the *cire perdue* process, for which reason we must assume that pride of craftsmanship—quite justified by their finest examples—rather than expediency must have determined their constant employment of this method.

In terms of the number of extant Islamicate celestial globes, this family is also important. Their workshop claims 21 signed globes—the largest number from a single shop. Moreover, it is very likely that not only the anonymous globe now at the Smithsonian Institution (No. 38) but also a considerable number of other Indo-Persian seamless metal globes could be attributed to this workshop, including Nos. 39–44. One of the globes signed by Ḍiyāʾ al-Dīn Muḥammad (No. 28, see Figures 43 and 47) is known to have inside it three rolled up pieces of paper with writing on them (possibly amulets?), which have been sewn together and appear to have at one time been wrapped around a rather long heavy metal probe. The diameter of the probe is greater than that of the holes in the globe. Since there are no missing plugs or any other way to gain access to the inside except through the quite small holes at the poles, these items have not been examined up to this time. It seems that they must have been placed in the globe by the maker before the final plug was set into place. Was this a common practice in globe manufacturing? Would attempts to retrieve such items account for the considerable number of globes that have missing plugs (see Figure 36)? Another explanation for some of the plugs being purposefully removed might be that seamless cast globes sometimes have pebbles or bits of grit left in them

from the casting process, and when shaken, they rattle (for example, Nos. 40 and 42). People may have hoped to find a treasure in them and forced an opening by removing a plug.

We know that there were other scientific instrument makers in Mughal India besides this particular family. One, an astrolabe maker for Humāyūn, was Mawlānā Maqṣūd Hirawī, who "was one of the devotees of the Resident of Paradise [i.e., Humāyūn]. . . . He manufactured astrolabes, globes and other instruments in such a manner that observers of his products were filled with wonder."[155] Unfortunately, none of his celestial globes or astrolabes are known to be extant. During the reigns of Akbar and Jahāngīr the craftsman ᶜAlī ibn ᶜIwaḍ produced two known astrolabes,[156] while during Shah Jahān's rule Ibn Muḥibb Ḥaqiqah made an astrolabe.[157] No globes are known to have been made by these two Mughal artisans.

Besides the Lahore family workshop, there was in the seventheenth century another maker in northwestern India who was producing globes that appear to be cast seamless globes. The instrument maker is known by three astrolabes[158] and two globes (Nos. 25 and 29). On the earlier globe, executed in 1070 H/AD 1659–1660 at the request of a certain Shaykh ᶜAbd al-Khāliq, the maker signed himself as Muḥammad Ṣāliḥ Tatahwī, while on the second globe, made in 1074 H/AD 1663–1664 he signs as Muḥammad Ṣāliḥ Tatawī. The spelling of Tatah-wī, which uses quite unusual orthography, is probably an attempt on his part to indicate the pronunciation of the name, for with the second spelling one might be inclined to pronounce it Tatwī. It seems unlikely that he was actually from Tatta in the delta of the Indus river as some have suggested,[159] since the name of the town is written with different characters and should more accurately be transliterated Ṭhaṭṭhā.[160]

Both globes by Tatawī seem to be quite precise with full sets of constellation figures, though the available photographs of his earlier globe show little detail. Of special interest is the fact that the second globe has the names of the constellations and the signature written in both Arabic and in Sanskrit (see Figure 18, which also clearly shows a plug from the casting process). One might speculate that this maker perhaps worked in the Kashmīr area, where at the end of the sixteenth century ᶜAlī Kashmīrī ibn Lūqmān may have produced his apparently seamless metal globe. Kashmīr was a region where Sanskrit was the language until replaced for official purposes by Persian in the late fifteenth century, and consequently might have been an area where a globe in both Arabic and Sanskrit would have been requested.

One other globe maker of the middle seventeenth century was producing globes that are apparently seamless cast metal. Luṭf Allāh ibn ᶜAbd al-Qādir al-Muḥibb al-Asṭurlābī made an undated globe (No. 67), probably working in northwestern India, since that is the only area which with certainty can be shown to have workshops employing the specialized technique. Little is known of this maker, except that his father produced four astrolabes, one of which is dated 1031 H/AD 1621–1622, which are generally considered Indo-Persian products.[161] Consequently, if the father was an active instrument maker around AD 1620, then it is likely that the son was working around 1650.

In the middle of the seventeenth century the entire course of the Indus river was under Mughal rule, as was Afghanistan to the west. An unusual and attractive painted wood globe, (No. 36, illustrated in Figure 19) may well have been made in Afghanistan. This globe, which appears by the star positions to have been made in the middle seventeenth century (although this is not an example of high-precision work), represents a slightly different iconography for the 48 constellation figures from any other known celestial globe or any known copy of ᶜAbd al-Raḥmān al-Ṣūfī's *Book of the Constellations of the Fixed Stars* or similar illustrated treatises that served as design books and guides to the placement of the stars within and around the constellations. The iconography and calligraphy of this globe suggest that a now unknown instrument maker was working in Afghanistan or Turkistan about the same time the Lahore family was excelling in their

FIGURE 18.—Globe No. 29, dated 1074 H/AD 1663–1664, by Muḥammad Ṣāliḥ Tatawī. London, private collection. (Photo: Alain Brieux)

production of cast globes.

In addition to the Mughal empire of India, two additional large empires dominated the central lands of Islam in the sixteenth and seventeenth centuries: the Ottoman and the Ṣafavid. A hallmark of the Ṣafavid rulers was their patronage of the arts. The Ṣafavid empire was centered in Persia, extending to the sub-Caucasus and Khurāsān south of the Oxus. During the reign of Shāh ᶜAbbās I (AD 1587–1629) the Ṣafavid empire was at its strongest and the artistic achievements of the court artisans and miniature painters were the most conspicuous.

One celestial globe (No. 63, illustrated in Figure 20) is known from an inscription on it to have been made for Shāh ᶜAbbās I in 1012 H/AD

FIGURE 19.—Globe No. 36, unsigned and undated. London, National Maritime Museum, Department of Navigation. (Photo: The National Maritime Museum, London)

1603–1604. Unfortunately the maker of this globe is unknown. This particular globe and two other Persian unsigned and undated globes (Nos. 82 and 83) are particularly interesting as examples of a separate tradition in Islamicate celestial globe design. These globes do not have constellation outlines depicted on them, but do have some stars that are rather poorly positioned. Rather, they have only the 12 zodiacal signs represented inside medallions. These zodiacal

FIGURE 20.—Globe No. 63, dated 1012 H/AD 1603–1604 and made for Shāh ᶜAbbās I. Chicago, The Adler Planetarium. (Photo: M. B. Smith)

signs are not used as guides to the positions of the stars near the ecliptic and are not derived from the illustrations of constellations found in astronomical texts, but indicate instead an alternate Islamicate tradition of displaying the zodiacal signs as emblematic motifs rather than as constellation diagrams. Taurus is a bull with a hump on his back and a bell round his neck; Libra a man sitting cross-legged with scales over his shoulders like a yoke; etc. (see Chapter 2 for further discussion of this iconography). All of these globes are constructed with a seam, indicating that they were made of two hemispheres. Consequently, whatever workshop in Ṣafavid Persia produced these globes, it did not employ the *cire perdue* process of making a seamless globe used by the contemporaneous Mughal workshop.

Evidence of cultural and artistic exchanges between Ṣafavid Persia and Mughal India is seen in the fact that the Mughal ruler Jahāngīr, a contemporary of Shāh ᶜAbbās I, prided himself on designing a series of coins employing motifs similar to those used in the zodiacal medallions of these three Persian celestial globes.[162] Jahāngīr recorded in his memoirs for the thirteenth year of his reign (AD 1617):

> Previously to this, the rule of coinage was that on one face of the metal they stamped my name, and on the reverse the name of the place, and the month and year of the reign. At this time it entered my mind that in place of the month they should substitute the figure of the constellation which belonged to that month; for instance, in the month of Farwardīn the figure of a ram, and in Urdībihisht the figure of a bull. Similarly, in each month that a coin was struck, the figure of the constellation was to be on one face, as if the sun were emerging from it. This usage is my own, and has never been practised until now.[163]

During the reign of Ṣāfī I, the successor of Shāh ᶜAbbās I, a well-known astrolabe maker,

Muḥammad Zamān, working in Mashhād in the northeastern part of the empire made a lovely globe with the full set of constellation figures (No. 16, illustrated in Figure 21) in the year 1050 H/AD 1640–1641 and another in 1054 H/AD 1644–1645 (No. 17). This maker also produced a third globe that is small and undated and has only the prominent stars indicated on it (No. 64). All of these globes are metal and bear an obvious seam, indicating that this Ṣafavid maker also did not produce seamless cast globes. Muḥammad Zamān is also known by seven astrolabes,[164] which span the years AD 1659–1677.

Other astrolabe makers are known to have been active in Ṣafavid Persia, such as Muḥammad Muqīm and Muḥammad Mahdī, both of Yazd southeast of Iṣfahān. The former made an astrolabe for Shāh ᶜAbbās II in 1647–1648, engraved by Faḍl Allāh al-Sabzawārī under the supervision of Muḥammad Shafī, the astronomer of Janābād,[165] while the latter made one in AD 1659–1660 for Ṣafī Qulī Bēg, an Amīr at the court of Shāh ᶜAbbās II.[166] They are known to have made a large number of other astrolabes and to have occasionally collaborated together on an instrument. Unfortunately, no celestial globes are known to exist by either of these Ṣafavid metal workers. It was more common in seventeenth-century Persia than elsewhere for two or more astrolabists to collaborate on an instrument as the maker and engraver or decorator. From the few known Ṣafavid globes, however, it is impossible to determine if the same custom was followed in globe production.

FIGURE 21.—Globe No. 16, dated 1050 H/AD 1640–1641, by Muḥammad Zamān. London, The Victoria and Albert Museum, Department of Metalwork. (Photo: M. B. Smith)

The father of Muḥammad Mahdī, Muḥammad Amīn, may well have been the astrolabe maker whom Chevalier Jean Cardin met in his travels through Persia as a French *merchand royal* at the court of Shāh ᶜAbbās II. In his journals Cardin provides a detailed description of the methods of constructing astrolabes in Ṣafavid Persia, but makes no mention of celestial globes, going so far even as to say that "the astrolabe is almost the only astronomical instrument of Persians."[167] It is indeed curious that the very prolific and famous Ṣafavid astrolabists at the end of the seventeenth and beginning of the eighteenth centuries, ᶜAbd al-Aᵓimma[168] and Khalīl Muḥammad (of Iṣfahān) are also not known to have made celestial globes.

A most unusual anonymous globe appears to be a product of early seventeenth-century Ṣafavid Persia. This globe, No. 81, which has only major stars and no constellation outlines, is unique in that lines are engraved on it to demonstrate the three methods of determining the coordinates of a star or planet (see Chapter 2). These clearly correspond to a geographical latitude of 32° north. This is the latitude of Yazd as well as the latitude of Lahore, but since the sphere is made in two hemispheres, we can conclude it is from Yazd rather than Lahore. Although there is some irregularity in the engraving of the circles and graduations, the globe is a fine example of metalwork, for the seam is not visible on the outside. Moreover, no plugs are observable, but when a probe is inserted a seam can be felt running along the line of the ecliptic. There are several visible cracks, which would suggest that it was formed of two cast hemispheres, put together with great expertise (see Figure 22 for an illustration).

While there are a considerable number of Islamicate celestial globes from the Mughal and Ṣafavid empires, only one comes with certainty from the contemporary Ottoman empire to the west, and that one example is from Egypt, which was a province rather than in the heart of the Ottoman empire. By the middle of the sixteenth century the Ottoman empire, centered in Anatolia, extended eastward to the borders of the Ṣafavid empire and westward to Algeria. There are only a few astrolabes known to have been made in the Ottoman empire, very few when compared with the numerous products of the Ṣafavid and Mughal realms.[169] The Ottoman rulers were not without a serious interest in astronomy, however, for they built an observatory in Istanbul in AD 1577 under the direction of Taqī al-Dīn Muḥammad al-Rashīd ibn Maᶜrūf. He had come to the Ottoman capital from Egypt and at this short-lived observatory had under him 15 astronomers and was himself the inventor of some new astronomical instruments.[170]

The globe discussed above bearing the signature of Jamāl al-Dīn Muḥammad al-Hāshimī al-Makkī and dated 981 H/AD 1573–1574 was probably not actually made in Arabia despite the maker's name. Quite certainly, however, at the beginning of the eighteenth century a celestial globe was produced in Egypt, at that time under Ottoman rule. An astonomer, instrument maker, and author by the name of Riḍwān ibn ᶜAbdallāh, called Riḍwān Efendī al-Falakī (the astonomer), lived in Būlāq (a district of Cairo), where he died in 1710.[171] Egypt had been part of the Ottoman empire since 1517, when Sulṭān Salīm I overthrew the Mamlūk dynasty in Egypt. From March 21 to sometime in July or early August of 1701 (the second of Shawwāl to Ṣafar, 1113 H) Riḍwān worked on and completed a celestial globe (No. 31) having a full set of constellation figures with stars positioned according to the tables compiled by Ulugh Bēg's observatory, with longitudes increased to correspond to his own period. This globe, which is clearly made in hemispheres and not cast in one piece, was made for Ḥasan Efendī al-Khalwatī Damurdāshī, at one time Rūznāmijī of Cairo. The title Rūznāmijī was given to the director of the astronomers of the Qalᶜat Rūznāmah (citadel of timekeeping) in Cairo. He made calculations and observations bearing on the determination of the calender.[172]

According to the Egyptian chronicler al-Jabartī (died AD 1822), Ridwān ibn ᶜAbdallāh made several instruments for Ḥasan Efendī in the years 1112–1113 H/AD 1700–1702, among them a small number of brass celestial globes on which

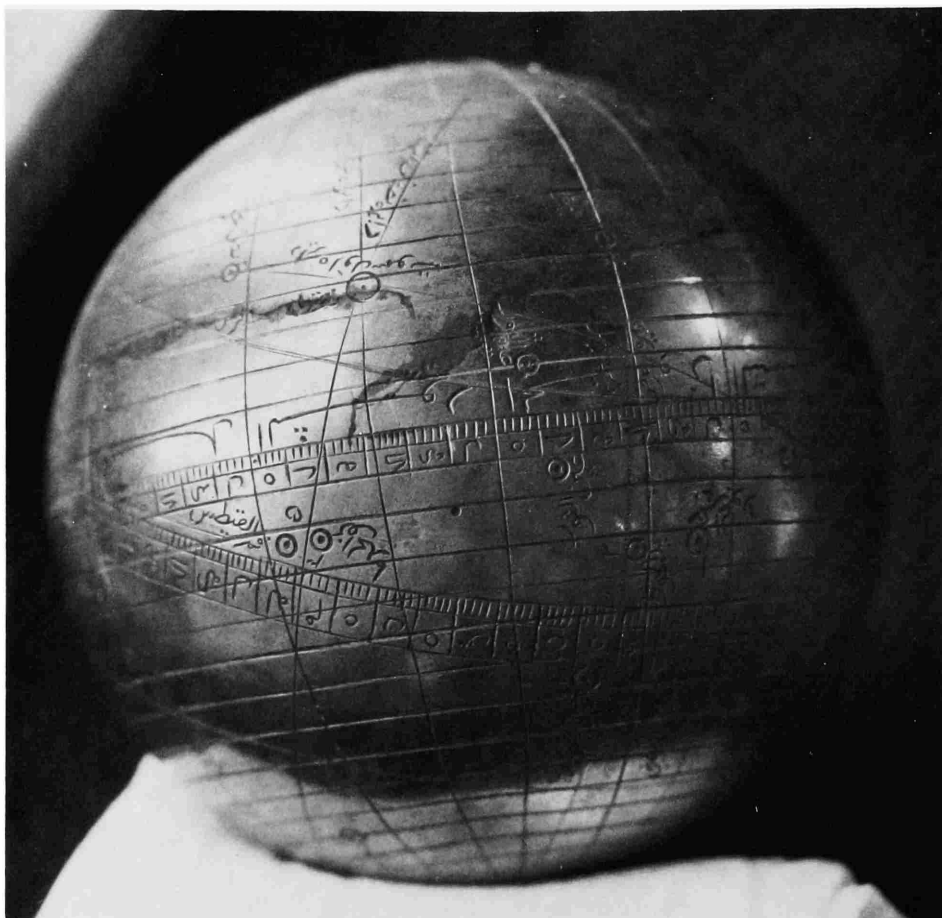



FIGURE 22.—Globe No. 81, unsigned and undated. Oxford, Museum of the History of Science. (Photo: M. B. Smith)

he engraved the visible stars and the constellations, with their names in Arabic, and the ecliptic latitude circles and meridians (*dawāʾir al-ʿurūḍ wa al-muyūl*), and then overlaid the globes with gold and sold them for an increased price. Riḍwān employed as an assistant Jamāl al-Dīn Yūsuf, a *mamlūk* (servant) and *kalārjī* (keeper of the cellar) to Ḥasan Efendī, who studied so diligently that he went on to compose treatises on shadows and lunar mansions and other technical subjects; he died 30 years after Riḍwān. Al-Jabartī states that both Yūsuf and Riḍwān's names were inscribed on a number of brass and gilded instruments made for Ḥasan Efendī in 1701 and before and after.[173] Yūsuf's name, however, does not appear on the one globe known to be extant, although Ḥasan Efendī is named as the patron and traces of the gilding are evident. The one extant globe also does not have meridians indicated on it, although they are specifically mentioned as being part of Riḍwān's design.

All other workshops producing Islamicate celestial globes in the eighteenth century seem to be from the eastern part of the Islamic world. There is a seamless cast globe dated 1121 H/AD 1709–1710 dedicated to a now unknown patron, which is quite certainly an Indo-Persian product (No. 32 of the catalog). It is a highly inaccurate globe with the stars arranged in a decorative manner and the constellations crudely and somewhat fancifully delineated. There are also two undated globes quite similar to this globe in

design and execution of both the sphere and rings (Nos. 45–46). The former has an undecipherable inscription around the base, and both have holes bored on either side of the globe about 25° from the equinoxes whose purpose is unknown. The latter globe has some interesting features to its somewhat whimsical iconography, including an extra bird in the form of a falling eagle near Cygnus (see Figure 23 for an overall view). These globes are such extreme examples

FIGURE 23.—Globe No. 46, unsigned and undated. Bloomfield Hills, Michigan, Cranbrook Institute of Science. (Photo: The Museum of the History of Science, Oxford)

of technically inaccurate and non-functional globes and display so many features in common that they suggest one workshop of perhaps even more recent date than the rather garbled inscription on No. 32 would indicate. They may be late nineteenth- or early twentieth-century imitations of Islamicate globes, perhaps produced by someone knowing very little Arabic and Persian, thus accounting for the apparently nonsensical inscription on No. 45, but still versed in the techniques of casting a seamless sphere, or having access to spheres cast by another artisan.

In north central India between AD 1728 and 1734 Mahārājah Sawā'i Jai Singh II of Jaipūr[174] constructed five observatories at Delhi, Jaipūr, Benāres, Mathurā, and Ujjain. For the Delhi observatory, which was completed first, Jai Singh acquired the *zarqalīyah* style of universal astrolabe, which had been made nearly half a century earlier by Ḍiyā' al-Dīn Muḥammad of the Lahore family workshop and which is of unusually large size (610 mm). Jai Singh tended in his design of the Indian observatories to rely upon greatly enlarged instruments to bring about greater precision rather than the smaller portable astronomical instruments.[175] The two astrolabes which he himself made[176] are of enormous proportions, each having a diameter of 2100 mm.

Jai Singh also directed the preparation of a set of astronomical tables named *Zīj Muḥammad Shāhī* after the Mughal ruler Muḥammad Shāh (AD 1719–1748) who appointed him governor of the state of Agra and later Mālwa in north central India. These tables were intended to update and improve those made by Ulugh Bēg in the fifteenth century. In a manuscript of these tables at Jaipūr it is said that the ecliptic coordinates (celestial longitude and latitude) used by Ulugh Bēg were converted to declination and right ascension (equatorial coordinates) by taking them from a celestial globe.[177] That is, presumably a rather large and well-made globe based on the positions of Ulugh Bēg's catalogue was used to find the coordinates of declination and right ascension (see Chapter 2 on the uses of celestial globes), thus avoiding the involved calculations requiring spherical trigonometry. Other than this one mention, however, celestial globes are not described as being among the astronomical instruments employed in the Indian observatories. Although Jai Singh himself was a Hindu, the work of the observatories represents for the most part the Islamicate tradition, just as the language employed was Persian, influenced by some European contacts and works such as the tables of Philippe de La Hire, which were translated into Persian for comparison with the *Zīj Muḥammad Shāhī.*

By a century later, however, these Indian observatories were neglected and in ruins.[178] Yet in 1842 a Hindu metalworker named Lālah Balhūmal Lāhūrī (that is, from Lahore) made an Islamicate celestial globe (No. 33) for a Sikh patron named Nihāl Singh Ṣāḥib Bahādur Ahluwālīyah. From about AD 1750 the Sikhs had taken over the Punjāb, and during the following 30 years had organized it into 12 loosely-knit states or *misls*, one of which was Kapūrthalah, ruled by the Ahluwālīyah family. The capital of this *misl* was the town of Kapūrthalah where this globe was placed, according to the lengthy Persian inscription on the sphere. Thus it is certain that the globe was constructed for Nihāl Singh who ruled Kapūrthalah, only a few miles southeast of Lahore, from October of 1837 until his death on 13 September 1852. Nihāl Singh had intermittent quarrels and disagreements with the Mahārājahs of Lahore, Ranjit Singh and his successors, so that during the Sikh war of 1845 Nihāl Singh failed to align himself clearly with either the Sikh or British side, for which reason some of his lands were taken by the British. When the second Sikh war occurred he gave immediate assistance to the British, after which he was then made a Rājah and apparently ruled rather popularly over his subjects until his death.[179]

Lālah Balhūmal Lāhūrī, who is also known by at least five astrolabes,[180] cast the globe in one piece, for no seam is visible and the plugs arising from the *cire perdue* process can easily be seen. This fact, in addition to his *nisbah* (the part of the name indicating place of origin) being Lāhūrī, strongly suggests that the process of casting globes in which the sixteenth- and seventeenth-century Lahore workshop specialized continued to be practiced for more than 150 years after

Ḍiyā⁾ al-Dīn Muḥammad. Many of the apparently seamless cast globes may have been produced by workshops in the Lahore area over a period of 250 years. Since we know of no written treatises on the technical construction of a seamless globe by *cire perdue* it is likely that a system of apprentices was required to maintain sufficient skill in the technique to produce a globe of first rate quality such as the one made in 1842. Lālah Balhūmal exhibits considerable skill in the execution of this globe (see Figure 24), on which he placed a long Persian inscription describing the

FIGURE 24.—Globe No. 33, dated 1258 H/AD 1842, by Lālah Balhūmal Lāhūrī; present location unknown. (Photo: From the Files of the Whipple Museum of the History of Science, Cambridge)

globe, the patron, and the fee he received as maker. Though he was probably a Hindu and his patron a Sikh, the globe is a typical Islamicate celestial globe with the standard set of 48 constellation outlines and a stated 1022 stars, labeled in Arabic, thus maintaining the basic design evident in the earliest of the Islamic globes made 762 years earlier in Spain. A second celestial globe was made by Lālah Balhūmal in the same year (see No. 127 in the Catalog, Chapter 6).

There is a striking similarity between the design of these globes made by Lālah Balhūmal Lāhūrī in 1842 and an anonymous celestial globe with Sanskrit inscriptions (No. 54, illustrated in Figure 25). The similarity extends to the stands and rings, methods of construction, and star positions, leading to the inevitable conclusion that both globes were either produced by Lālah Balhūmal or someone trained in his workshop and familiar with his technique and design. Although the constellation names and the numerals are written in Devanāgarī characters, it is completely within the Islamicate tradition in design and execution.[181]

A third example, an anonymous globe with only the major stars (No. 90), can also with some certainty be attributed to the Lālah Balhūmal Lāhūrī workshop. It displays the same precision of execution, the same basic method of construction, the same star positions (though only 32 of the major stars are represented on the globe), and the identical distinctive arrangement of meridian circles. On all four globes (Nos. 33, 54, 90, and 127) there are a set of six great circles

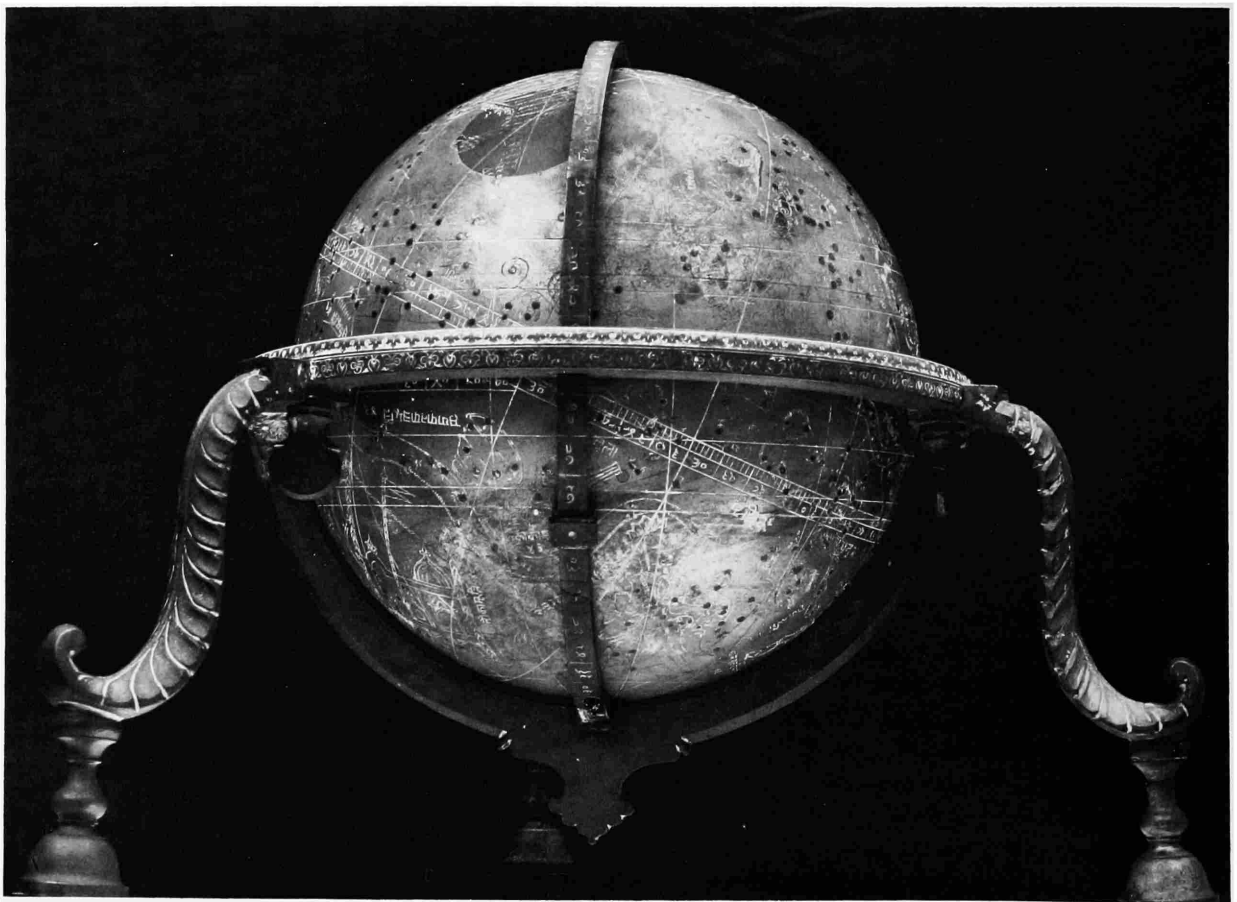



FIGURE 25.—Globe No. 54, unsigned and undated; engraved in Sanskrit, Devanāgarī characters. Columbia University, David Eugene Smith Collection. (Photo: Columbia University)

serving as meridians, which intersect the equator at 30° intervals; they do not begin at the vernal equinox but rather are shifted 6° westward, so there is no meridian representing the equinoctial colure. For these reasons this anonymous globe can also be assigned to the nineteenth-century workshop of instrument makers in Lahore (see Figure 26).

A fifth globe (No. 53) has the same unusual arrangement of meridian circles; however, from the available photograph it is very inaccurately constructed, and its lack of precision stands in

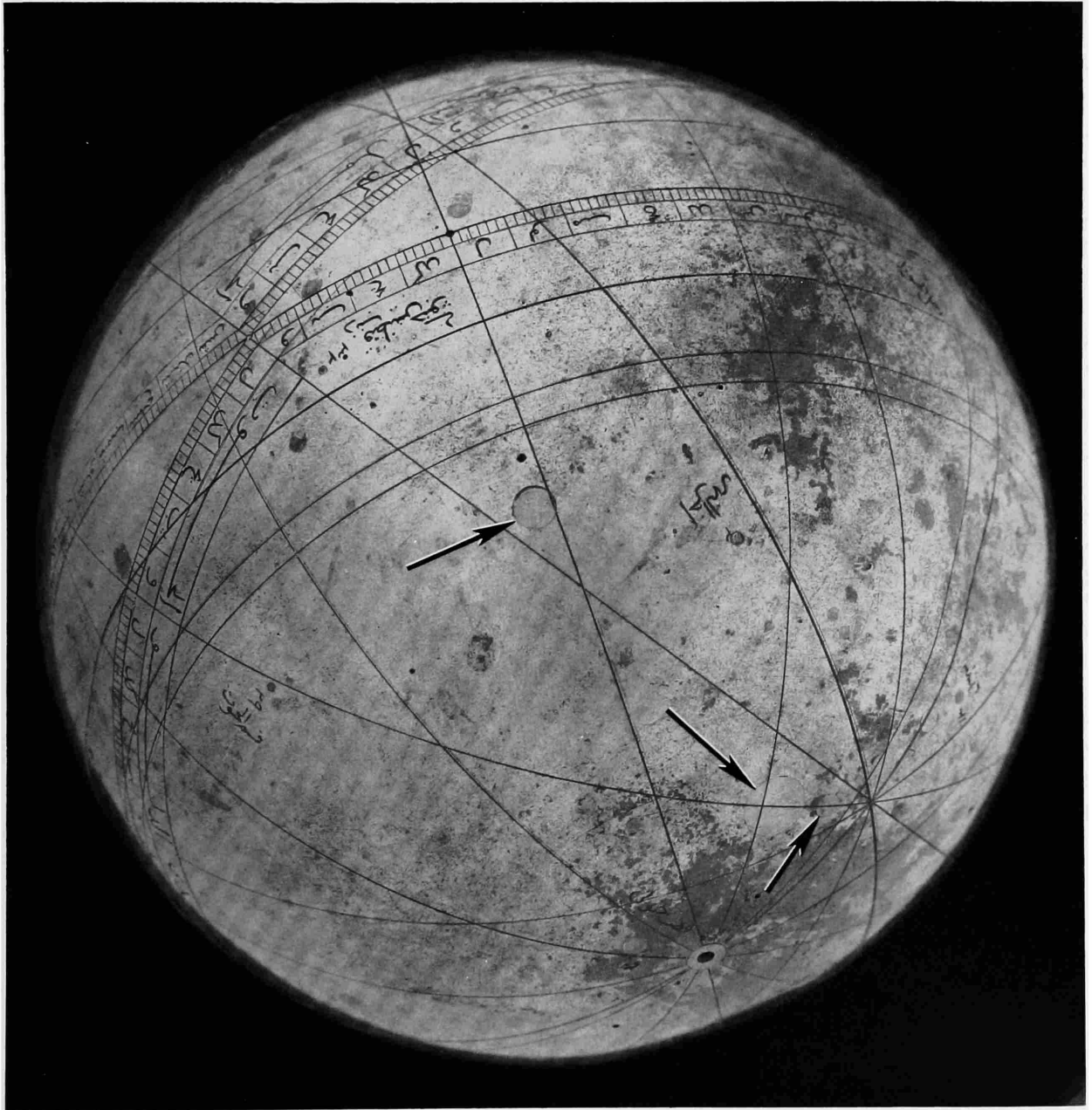



FIGURE 26.—Globe No. 90, unsigned and undated. Rockford, Illinois, The Time Museum. Arrows indicate plugs. (Photo: Courtesy of The Time Museum, Rockford, Illinois)

considerable contrast to the fine execution of the other four globes. Neither its size nor the method of construction is known, but its general appearance suggests that it is a later copy of a globe of the Balhūmal workshop design, executed by a metal worker who was not a professional instrument maker.

At about the same time as the instrument maker Lālah Balhūmal Lāhūrī was working in the Punjāb, another metalworker was making a celestial globe (No. 92) in Transoxiana for Muḥammad ᶜAlī Khān, who ruled as the eighth Khān the area of Khokand east of Bukhārā AD 1822–1842.[182] The maker did not sign the globe, which was produced in 1241 H/AD 1825–1826. It has no stars on it and is made of two metal hemispheres.

Of the globes having no stars on them, all but five of those inspected have a seam. The seam is not always visible (for example, on Nos. 100, 103, and 105), but there are no plugs visible, and when a probe is inserted inside, a clear seam or ridge can be felt running around the sphere. Since the majority of globes without stars have seams, this would suggest that most of them were made outside of northwestern India, which appears to have specialized in seamless globes cast by the *cire perdue* process—perhaps in Ṣafavid Persia. Most of these globes (Nos. 95 through 110) seem to be related stylistically as well, suggesting that they were produced in the same workshop. No. 97 has a patron's name, Mīrzā Muḥammad Taqī Khaṭarāt, who is said to be a *mujtahad*, or a Shīᶜite authority on religious jurisprudence. Since five of them appear to be seamless and exhibit plugs from the casting process, some Indo-Persian workshops in northwest India may well have produced them (an example of a seamless globe lacking stars can be seen in Figure 34).

Of the globes that have no stars or constellations, only two are dated. In addition to the one made in Transoxiana for Muḥammad ᶜAlī Khān, there is one globe (No. 91) dated slightly earlier, 1238 H/AD 1822–1823. It has no visible seam but neither has it any detectable plugs, and examination of the interior was not possible; therefore, it cannot at this point be classified as to the method of construction. The maker's name is quite difficult to read with certainty, but seems to be Muḥammad Samᵓī Tarī, and the calligraphy and engraving style would suggest a Persian rather than Indo-Persian origin. Since there are no star positions indicated on this class of globe, one cannot estimate an epoch for which the undated ones were designed. Most of the extant globes of this class are somewhat carelessly executed with irregular graduations and uneven circles. There are, however, some examples of quite precisely made globes, such as No. 93 (illustrated in Figure 27), which is a *papier mâché* globe in quite poor condition, and No. 98.

A seamless cast globe made in 1241 H/AD 1825–1826 by Muḥammad Karīm might possibly have been made outside of India (No. 74). Nothing is known of this maker,[183] but his name, the use of the Yazdijird era on the globe,[184] and the calligraphy suggest that he was from Persia rather than India. The well-made seamless globe has about 80 stars and no constellation outlines. If it was indeed produced in Persia rather than India, this would be evidence of an exchange of ideas and techniques between the artisans of Persia and those of northwestern India.

In the nineteenth century there were active three celestial globe makers whose styles differed considerably from each other and from the Indo-Persian products of the same period. A very fine globe exhibiting remarkable precision of design and execution was made by Muḥammad Ashrāf Tūqādī Zādah in 1215 H/AD 1800–1801. The small globe (No. 72) is made of painted wood, or possibly ivory, and the stand and rings are contemporary, for the maker has signed and dated them as well. The globe has no constellations but about 50 stars marked by dots. There are a set of meridian circles crossing the equator at 30° intervals, but no ecliptic latitude circles (possibly indicating European influence in design). It also has drawn in very fine ink a complete set of parallels at 2° intervals north and south of the equator, and another complete set of 2° intervals parallel to the ecliptic. It is likely that the maker of this globe of unusual design was from Persia

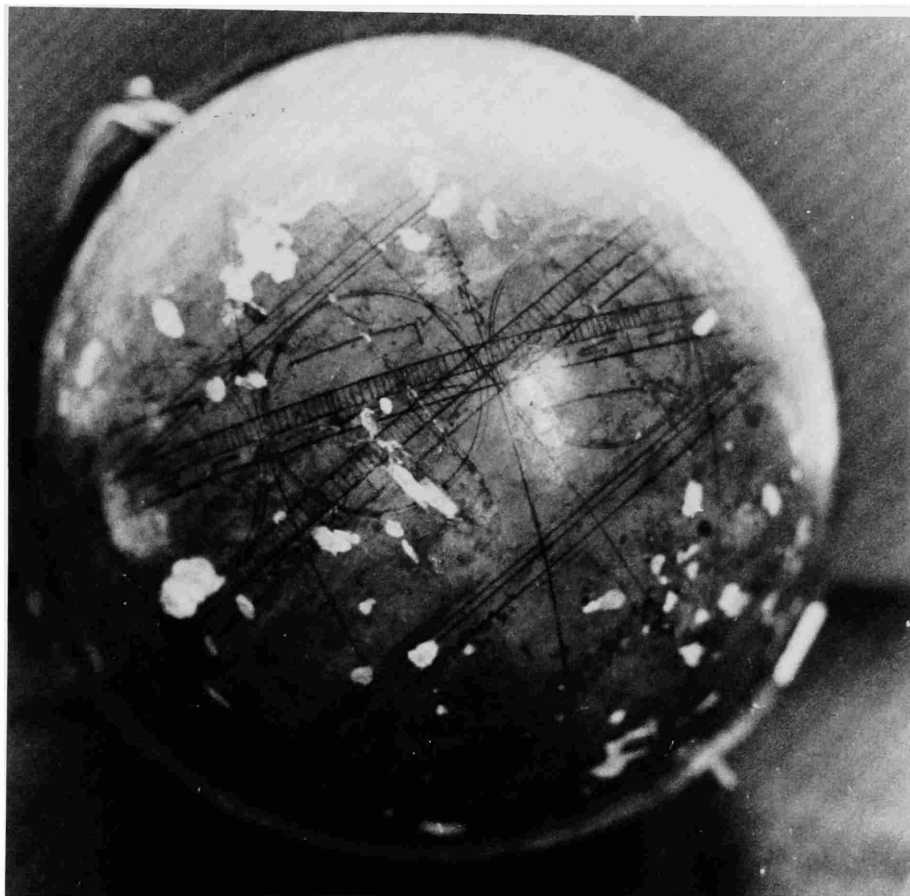



FIGURE 27.—Globe No. 93, unsigned and undated. Oxford, Museum of the History of Science. The covering plaster on this globe has deteriorated in some places. (Photo: M. B. Smith)

or Afghanistan, though we have no other products by him and no information concerning his work.

The design, precision, and calligraphy of the anonymous globe (No. 76) are strikingly similar to that signed by Muḥammad Ashrāf Tūqādī Zādah. This globe, illustrated in Figure 28, of painted paper on wood has both meridians and ecliptic latitude circles with a most unusual network of half-great circles originating at the intersection of the celestial equator and the solstitial colure at the winter solstice and extending to the equinoctial colure at 5° intervals, with this hemisphere also covered by a series of parallels at 1° intervals. The purpose of the network—unique among extant globes—is unknown. The longitudes of the stars indicate an epoch of the end of the eighteenth century.

Another quite different but equally unusual globe was finished by Muḥammad ᶜAlī al-Ḥusaynī on 23 Jumāda I 1221 H/9 August AD 1806. This is a painted and lacquered *papier mâché* globe (No. 73) of fairly large size. It is a technically inaccurate and nonfunctional globe with stars indicated by disproportionately large gilt dots on the dark rich brown ground. An incongruous element on such an inaccurate globe is the statement inscribed at each solstice that the obliquity of the ecliptic is equal to 23°30′17″. Only the 12 zodiacal constellations are represented pictorially in red, black, and gilt paints. The zodiacal figures are not actually constellation outlines, for

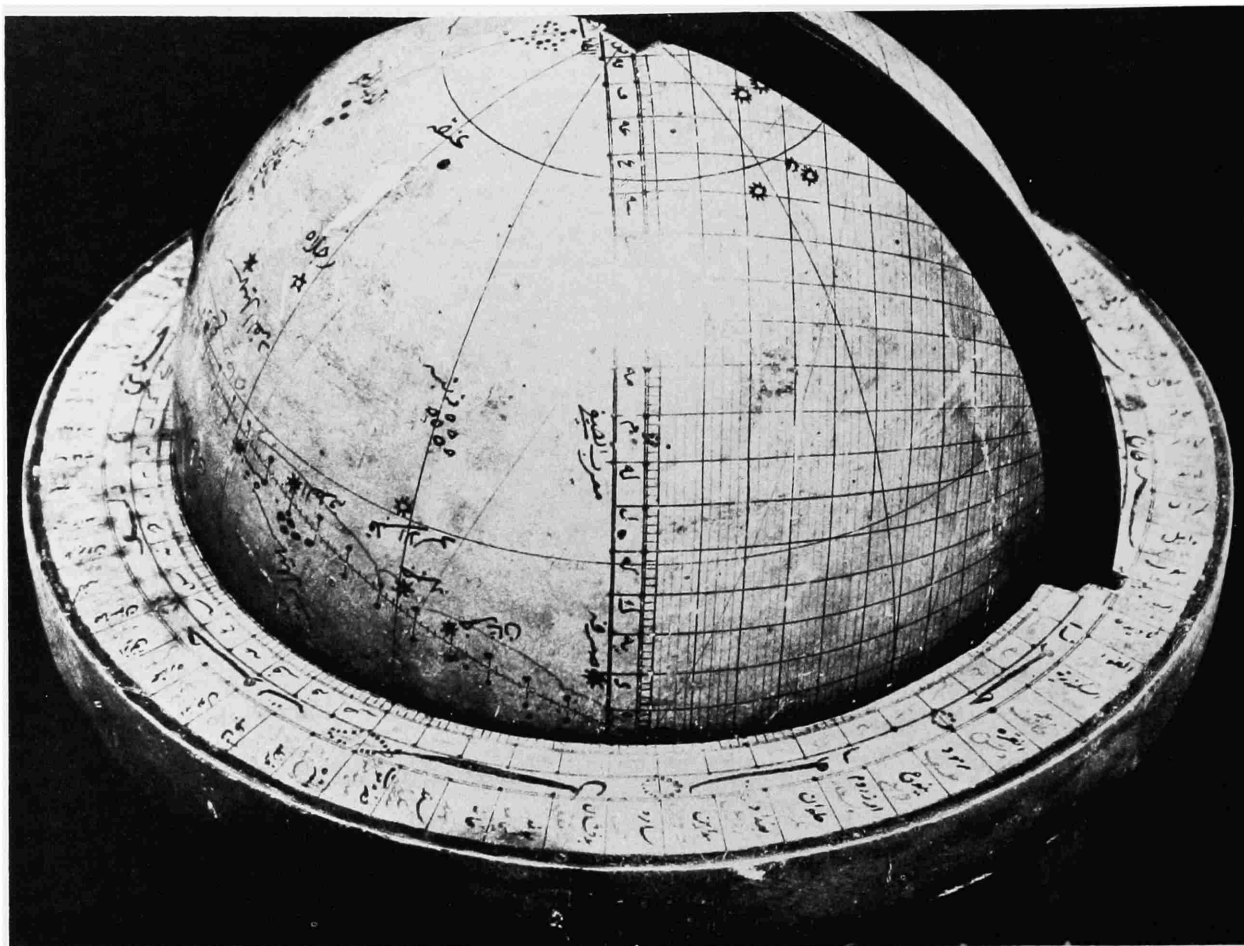



FIGURE 28.—Globe No. 76, unsigned and undated. Damascus, Musée Nationale. (Photo: The History of Science Museum, Oxford)

no stars are indicated in them. They are somewhat reminiscent, though by no means identical to, those figures of the Persian iconographic tradition evident on the globe made in the sixteenth century for Shāh ᶜAbbās I (No. 63, illustrated in Figure 20). There are, however, also similarities with the zodiacal figures which are depicted, along with the other constellation forms, on an anonymous *papier mâché* globe (No. 56; see Figure 29). On the latter globe, the constellation figures are not outlines of asterisms, for there are no stars on the globe, and they are depicted with an iconography radically different from that usually found on Islamicate celestial globes, which is associated with the al-Ṣūfī manuscript tradition and forms the basis of most constellation design on scientific instruments.

Late in the nineteenth century the only globe we know to come from Ottoman Turkey (No. 75) was made by "a student of the Normal School" Ḥusayn Hüsnü Kanqarī on 3 Rabīᶜ I 1299 H/23 January AD 1882. This globe, which is in two metal hemispheres, has meridians and ecliptic latitude circles, probably indicating some European influence. The graduations are labeled in standard rather than *abjad* numerals, a very unusual feature. It is unique among all the globes in having the names of the zodiacal figures written with the top of the writing toward the north (see Chapter 2 for further discussion of this char-

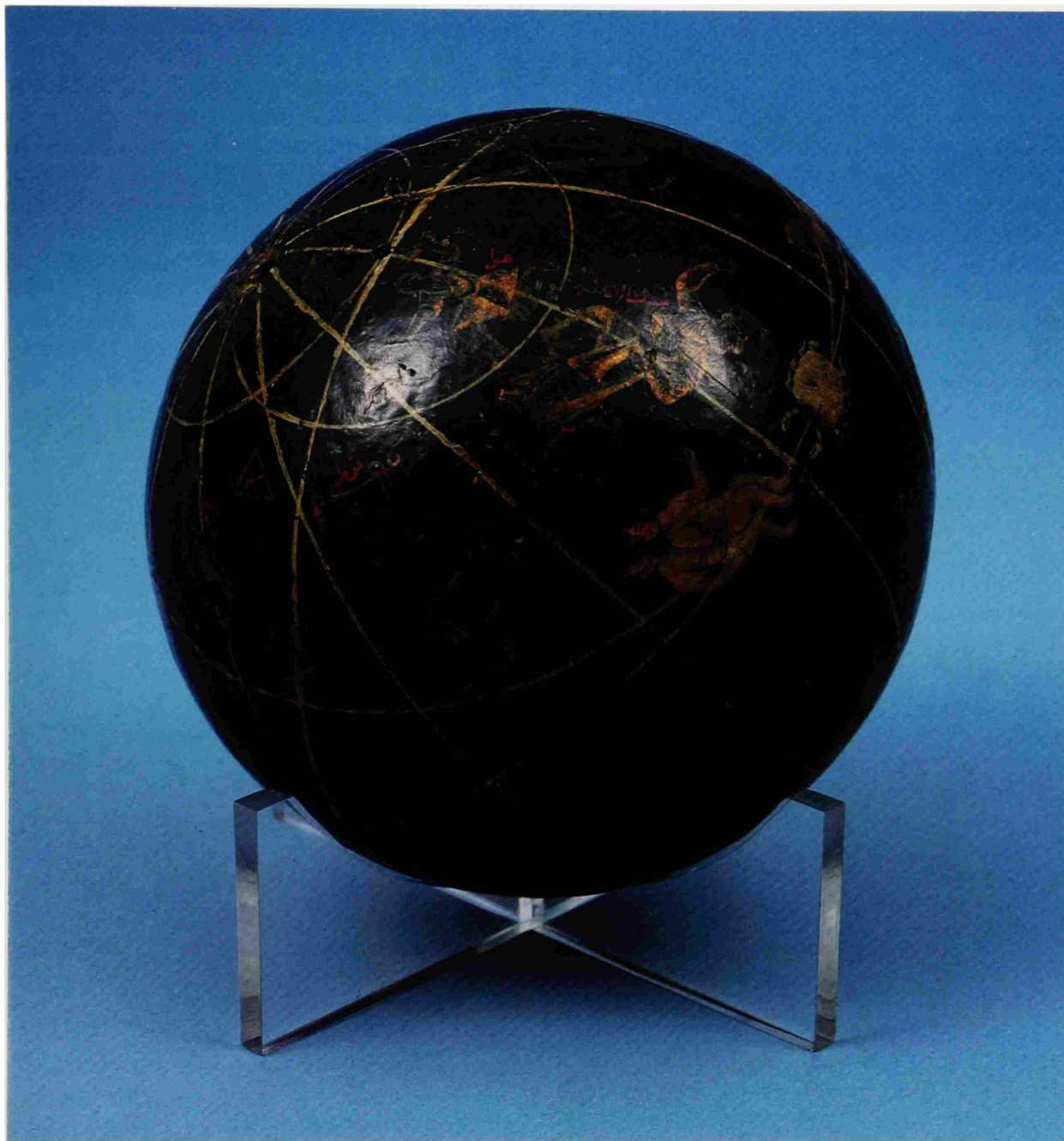



FIGURE 29.—Globe No. 56, unsigned and undated. London, National Maritime Museum, Department of Navigation. (Photo: The National Maritime Museum, London)

acteristic of Islamicate globes); this reversal may again show European influence. The star positions are quite imprecise and varied, although the graduations and circles are well executed. This Turkish globe is the most recent Islamicate globe included in this study.

It is evident that the Indo-Persian metal-workers and astrolabists of northwestern India per-

fected the difficult process of casting a seamless hollow metal globe by the *cire perdue* process, practiced this technique, and taught it to others from the late sixteenth century to the middle of the nineteenth century. It is impossible to say who first developed this extremely complex method of construction. Two examples seem to predate the sixteenth century: that of Muḥammad ibn Maḥmūd al-Ṭabarī (No. 6), dated 684 H/AD 1285–1286, and that of ᶜAbd al-Raḥmān ibn Burhān al-Mawṣili (No. 60), dated 718 H/AD 1318–1319. This implies the existence of a thirteenth-century workshop in Persia and an early fourteenth-century one in Mesopotamia which could produce such spheres. Yet there are problems with the validity of these globes. Even if they were actually executed at the time stated on the globes, it is strange that no other examples of the technique occur before the end of the sixteenth century. Nonetheless the two early examples display complete mastery and much experience with the technique.

During the eight hundred years in which the extant Islamicate celestial globes were made, from regions as diverse and distant as southern Spain and northern India, there was no change in the basic design of the globe, except for the apparently late and Persian development of a type of globe having no stars at all. While the depiction of the constellation figures could be adapted (within certain limits) to the local artistic conventions, the number and form of the constellations and the stars remained constant. The newly recorded stars and constellations of the southern hemisphere, resulting from the European explorations of the sixteenth century,[185] were never represented on an Islamicate globe. The number of the constellations and stars on Islamicate globes, including the two known Sanskrit globes that are also to be considered part of this tradition, is always derived from al-Ṣūfī's or Ulugh Bēg's star catalogs or from the earlier Ptolemaic one, which had only minor differences among them. On globes having only a selection of the most prominent stars, the choice of which stars to use depended on the designer and could vary, just as they did on astrolabes. Nonetheless the basic design remained unchanged. In the matter of construction, however, considerable experimentation and development seems to have occurred. During these eight hundred years globes were made in metal hemispheres, made of painted wood or *papier mâché* over a wood core, or were cast as a hollow seamless metal globe by the *cire perdue* process. This last method, which is not mentioned in any written discussion of celestial globes, either European or Islamicate, appears to be a distinguishing feature of Indo-Persian celestial globe making: that is, although the technique may possibly have developed earlier and elsewhere, it became the hallmark of the workshops located in the Punjāb and Kashmīr areas of northwestern India.

2. The Nature, Use, and Construction of Islamicate Celestial Globes

That inverted Bowl they call
the Sky
Whereunder crawling coop'd we
live and die,
Lift not your hands to It for
help—for It
Rolls impotently on as You
or I.

Edward Fitzgerald
The Rubāiyāt of Omar Khayyām

Today there are known to be 126 extant Islamicate celestial globes spanning a period from the eleventh to the nineteenth centuries and originating from regions as far west as Spain and as far east as the Punjāb and western Himālayas. (See the Catalog, Chapter 6, for detailed descriptions; an Addendum to the Catalog describes six additional globes not included in the analyses.) All the globes represent a tradition of instrument design which can be traced back to the Greek and Roman worlds. The language used in inscribing the majority of the globes is Arabic, although Persian, Indo-Persian, Ottoman Turkish, and even Sanskrit occur on some globes. The constellation and star names and other astronomical nomenclature is nearly always in Arabic, except for the two globes bearing Sanskrit inscriptions in Devanāgarī characters. The other languages, with only a few exceptions, occur in the imprint inscriptions—that is, those giving the maker, date, and sometimes the patron. These extant Islamicate globes can be grouped into three basic types that we shall now describe in detail.

The first type of globe, Class A, displays constellation outlines and depicts approximately the full set of those visible stars listed in star catalogs, such as those by Ptolemy, ᶜAbd al-Raḥmān al-Ṣūfī, and Ulugh Bēg.[1] These globes have the full set of 48 constellation figures recognized from Hellenistic times, but their appearance (e.g., the clothing) was modified to conform to the artistic conventions of the particular period and location where the globe was produced (see Figures 6, 9, 13, and 15). Of the 58 globes placed in this category, 25 are unsigned and undated. Three of the undated globes should perhaps form yet a fourth category of globes, for while they have constellation figures, they lack stars (Nos. 55, 56, and 58, one of which is illustrated in Figure 29). For the sake of convenience, however, they have been categorized as Class A globes. The 33 dated globes range in date from AD 1080 to 1842.

The second type of globe, Class B, has indicated on it only the major stars, varying in number from 20 to 150, with no constellation outlines (see Figures 7, 10, 22, 26, and 28). The choice of which stars were included on a globe of this class seems to have depended upon the maker, though those termed "astrolabe stars" in the star catalogs were nearly always included. There are 32 Class B globes in the catalog, of which approximately half are unsigned and undated. The remaining 17 globes date from AD 1140 to 1882. Among the Class B globes there have been included four globes that have zodiacal figures as well as the major stars (Nos. 63, 73, 82, and 83; No. 63 is illustrated in Figure 20).

The third type of globe, Class C, has neither stars nor constellations but displays those great circles[2] that are common to all three types of globes as well as some lesser circles (see Figures 27 and 34). In this class there are 34 globes, only two of which are dated, both from the first quarter of the nineteenth century.

While there are a few Islamicate globes made of painted wood or *papier mâché* on wooden cores

(see Figures 19, 27, 28, and 29), the majority are metallic. More shall be said later of their methods of construction.

The three classes described above do not completely exhaust the 126 globes described in the catalog in Chapter 6. That catalog includes at the end two globes for which it was impossible to obtain sufficient information to classify them. An addendum lists six additional globes.

The celestial globe represents the sphere of fixed stars (without the planets or "wandering stars" as they were sometimes called) as seen from *outside* the sphere rather than from the earth at its center.[3] A celestial globe in Arabic is called *al-kurah* (the sphere) or occasionally *al-kurah dhāt al-kursī* (the sphere possessing a stand) or *kurat al-samāʾ* (the globe of the sky).[4]

On every extant globe the great circle of the ecliptic (the apparent annual path of the sun in the heavens) is clearly marked. The poles of the ecliptic are prominently indicated, for through them pass six great circles that intersect the ecliptic at right angles and divide it into 12 sections of 30° each (see Figure 30). These great circles are not used today in astronomy and so do not have a common name, but can be termed ecliptic latitude circles. They are circles along which the celestial latitude is measured.[5] It should be noted that meridians (great circles at right angles to the celestial equator) are rarely found on Islamicate celestial globes.[6] The ecliptic latitude circles were used on Islamicate globes because in the Arabic-speaking world, as in the earlier Greek world, the coordinates of a star were most commonly measured by the celestial longitude or the distance measured from the vernal equinox eastward along the ecliptic, and by the celestial latitude measured north or south from the ecliptic along a great circle at right angles to it.[7]

The Arabic term occurring on celestial globes for such circles at right angles to the ecliptic is *dāʾirat al-ʿarḍ*, sometimes written *dāʾirat ʿarḍ*, (latitude circle; plural, *dawāʾir al-ʿurūḍ*). This is the circle along which the celestial latitude is measured, to be distinguished from the term for parallels or circles of latitude, *madārāt al-ʿurūḍ* or *madārāt ʿurūḍ*, which are circles parallel to the ecliptic.[8] In the discussion that follows and in the catalog of globes I use the term ecliptic latitude circle when referring to such great circles passing through the ecliptic poles. This reflects the Arabic terminology, since there is no commonly used term for them in modern astronomical nomenclature.

On nearly all Islamicate globes the names of the 12 zodiacal houses are inscribed along the ecliptic, each name filling the appropriate 30° interval.[9] For a celestial globe to function properly for northern geographical latitudes it must be oriented with the north pole up. On Islamicate globes the zodiacal names are written so that they appear to be upside down when the globe is set in this position.[10] The reason they were always written in this fashion lies in the way the Arabic language is written and read. For Latin, Greek, and modern European languages, when the globe is oriented with the north pole up, the sequential order of the zodiacal houses as they appear along the ecliptic has the same sinistrodextral direction as the writing. The nature of the Arabic alphabet, however, required that the names of the zodiacal houses be written in what seems to us an upside-down manner in order to maintain the flow of the order.

To give an example using the Latin alphabet, if the sequential order of the houses were from right to left along a line, then when labeling the houses in the Latin alphabet, which is written in the opposite direction left to right, the words must be inverted.

ARIES TAURUS GEMINI (printed upside down)

←

GEMINI TAURUS ARIES

Only when the labeling is turned upside down will the correct order be maintained. Since the *actual* order of the houses on a globe is left to right, and Arabic is written right to left, a similar situation results in which the names appear to be upside down. The same is true of the *abjad* numerals with which the ecliptic and equator are usually labeled (numerals that are letters of the alphabet assigned numerical values). The fact that the names of the zodiacal houses and the numerals appear to be right side up only when

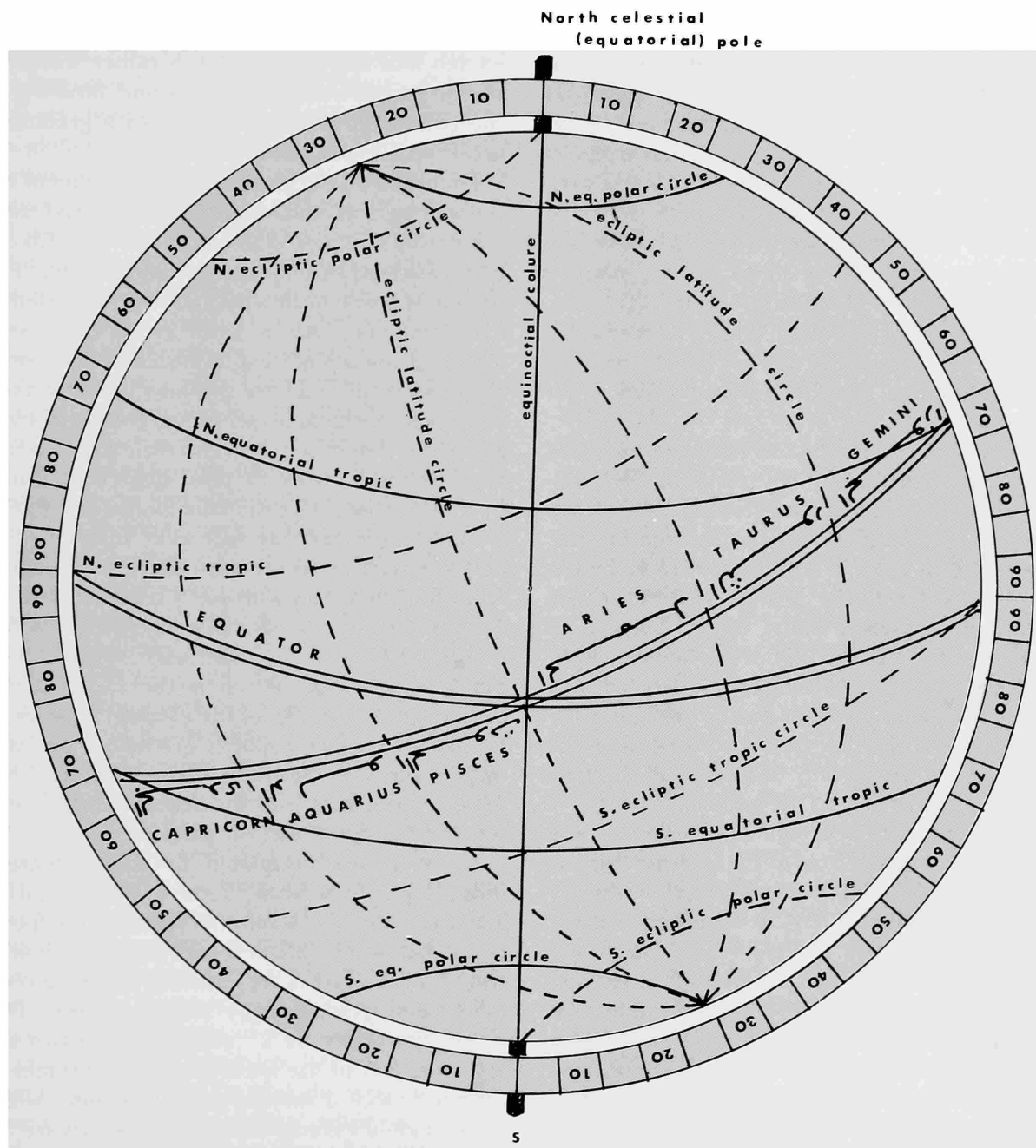



FIGURE 30.—Basic design of extant Islamicate celestial globes, with attached rotatable meridian ring.

the globe is oriented with the south pole up does not mean that Islamicate globes were set in the stands with the south pole up. On the contrary, it is specifically stated in all the literature and required by labeling on extant rings that the globe be mounted with the north pole up for use at northern geographical latitudes. And there would in actuality have been almost no need to use a globe for southern geographical latitudes, although some rings do have holes for mounting

the globe for arbitrarily chosen southern geographical latitudes. Having the labeling in an apparently upside-down position probably did not present as large a problem to the user as we might think. Most globes would have been placed on a table lower than eye level and the user would probably have stood over it. The Arabic names of the zodiacal signs that appear on the globes are as follows: *al-ḥamal* (Aries), *al-thawr* (Taurus), *al-jawzāʾ* (Gemini), *al-saraṭān* (Cancer), *al-asad* (Leo), *al-sunbulah* (Virgo), *al-mīzān* (Libra), *al-ʿaqrab* (Scorpio), *al-qaws* (Sagittarius), *al-jadī* (Capricorn), *al-dalw* (Aquarius), and *al-ḥūt* (Pisces).

A few Class A globes also have the names of the 28 lunar mansions[11] written along the ecliptic, usually at intervals of about 12½°, designated by a small dash intersecting the ecliptic. The fact that the zodiacal houses are along the ecliptic gives rise to the term used for the ecliptic on Islamicate globes, that is, *dāʾirat minṭaqat al-burūj* (the circle of the belt of the houses), while the two poles of the ecliptic are labeled *quṭb minṭaqat al-burūj shamālī* (*janūbī*) (the north [or south] pole of the belt of the houses), or sometimes simply *quṭb burūj shamālī* (*janūbī*) (the north [or south] pole of the houses).[12]

At an angle of approximately 23½° to the ecliptic,[13] the great circle of the celestial equator or equinoctial, *dāʾirat muʿaddil al-nahār* (the circle of the equality of day), is indicated crossing the ecliptic between the Houses of Virgo and Libra and between the Houses of Aries and Pisces. At the celestial poles—that is, the poles of the celestial equator that are immediately over the terrestrial poles, the two points in the heavens toward which the earth's axis is directed—there are nearly always two holes through which the globe was mounted in a ring. These poles, when labeled, are called *quṭb muʿaddil al-nahār shamālī* (*janūbī*) (north [or south] pole of the celestial equator), or sometimes *quṭb shamālī* (*janūbī*) (north [or south] pole). On one globe (No. 113) the label reads *quṭb ʿālam shamālī* (north pole of the universe). The ecliptic poles, where the ecliptic latitude circles converge, occasionally also had holes.[14] In a truely functional globe these would not have been used for mounting the globe on its axis in a meridian ring, but rather would be useful during the construction and finishing of the globe and for the insertion of a graduated quadrant for measuring coordinates.

On nearly all the globes the great circles of the celestial equator and ecliptic are graduated, most frequently by single degrees with every fifth degree indicated by a longer line and labeled. The numerals labeling the graduations are written in *abjad* notation, that is, with certain designated letters of the alphabet used instead of the standard numerals.[15] There are also globes graduated by single degrees with every sixth labeled, and some by single degrees with every tenth labeled, and with every third degree indicated by a longer line. Occasionally globes are graduated by larger intervals, such as 2° intervals with no labeling, 2° intervals with every sixth degree labeled, 2° intervals with every tenth labeled, or by 5° intervals with each one labeled, or by 6°, or even 10° segments with each labeled. The Smithsonian globe, which is the focus of the present study (No. 38 of the catalog) appears to be one of only two globes graduated by half-degree intervals. (See the tables in Chapter 7 for details concerning the incidence of these and other characteristics of the globes.)

Those globes graduated by single degrees range in diameter from 55 mm to 330 mm, with a median size of 150 mm. As one might expect, the globes whose smallest unit of graduation is two or more degrees are generally smaller globes than those graduated by single degrees. The globes graduated by 2° intervals, with two exceptions, vary in size from 60 mm to 100 mm in diameter, with a median size of 70 mm, while the two globes graduated by 6° intervals are 50 mm and 60 mm in diameter, and the one globe using 10° intervals is 97 mm in diameter. Rather surprisingly, the four globes graduated by 5° intervals are fairly large, two having a diameter of 115 mm and two of 150 mm, just as there are two globes whose smallest unit is two degrees, which have diameters of 200 and 203 mm.[16] The unusually large size of these six globes is no doubt due to the fact that they are all Class A globes,

which tend to be larger than the other two classes of globes, obviously because they must accommodate over 1000 stars and 48 figures. Why the makers chose such a scale of graduation for these six globes is not known. The estimated diameter of one of the two globes using one-half-degree intervals (No. 53) would make it the largest of all the extant globes by a considerable margin, while the diameter of the Smithsonian Insitution globe, the only other globe graduated by such an interval, is the sixth largest of the extant globes whose diameters are known.

Several extant globes have graduations of the ecliptic and equator but have no numerical labeling, while 14 globes have no graduations at all, but rather simple lines representing the celestial equator and ecliptic. With only one exception, the numbers marking the degrees along the ecliptics repeat in 30° intervals: that is, starting at the vernal equinox, one finds along the ecliptic the numbers 5, 10, 15, 20, 25, 30, 5, 10, 15, 20, . . . or whatever series would be appropriate, such as 6, 12, 18, 24, 30, in the case of those graduated by 2 with every sixth labeled. The one exception to the repetition of 30° intervals on the ecliptic is again No. 38, the Smithsonian Institution globe. Its intervals along the ecliptic are numbered continuously from 5 through 360 beginning at the vernal equinox.[17]

Greater variety is to be found in the graduations of the equator. For the majority of the globes the graduations along the equator are numbered continuously from the vernal equinox. Some, however, are numbered in three consecutive segments of 100° each and a final segment of 60°. Some are labeled in two segments of 180°, and on two, the equator repeats every 30° as does the ecliptic, while on three the equator is numbered in four segments of 90° each. Two globes, both nineteenth-century western Indian products (No. 33, illustrated in Figure 24, and No. 53), number each 6° segment of the celestial equator with a single numeral, 1, 2, 3, . . . 59, 60, beginning with the vernal equinox.

The two points where the ecliptic crosses the celestial equator, the equinoxes, are not labeled as frequently as are those great circles themselves, but when their names are inscribed the terms used are *nuqṭat iʿtidāl kharīfī* (point of the autumnal equinox) and *nuqṭat iʿtidāl rabīʿī* (the point of the vernal equinox). Similarly, the solstices are seldom labeled, but on the eight globes where they are labeled, the terms *nuqṭat inqilāb ṣayfī* (*shatwī*) (point of the summer [or winter] turning) and *inqilāb shams* (turning of the sun) occur.

The solstitial colure is the great circle that passes through the northernmost point of the ecliptic, the summer solstice, and the southernmost point of the ecliptic, the winter solstice. This circle also passes through the ecliptic poles as well as the celestial (equatorial) poles, and thus is one of the six ecliptic latitude circles found on all Islamicate globes. The solstitial colure is rarely labeled, however. On only six globes does it bear a label, *dāʾirah marrah bi-l-aqṭāb al-arbaʿah* (the circle passing through the four poles).

The point on the ecliptic that is the greatest distance from the equator, measured along the solstitial colure, is frequently labeled on globes. On 25 globes, all but one of Class B or C, the words *mayl kullī* are written along the segment of the solstitial colure between the equator and ecliptic. Thus, the term occurs twice on such a globe on opposite sides near the solstices. The term *mayl kullī* means "complete obliquity (or declination)"—that is, the greatest obliquity or distance of a point on the ecliptic from the equator.[18] When discussing the globes in the Catalog (Chapter 6), I have used the term *mayl kullī*, rather than an English equivalent, to indicate when these two labels are found on a globe. On only three globes is the actual value of the obliquity specified.[19]

On many globes a great circle is drawn through the equinoxes and the celestial poles, and perpendicular to the solstitial colure. This great circle, the equinoctial colure, is nearly always indicated on those globes having no stars (Class C) and on approximately one-third of the globes having only the prominent stars and no constellation outlines (Class B), but it occurs on only four of the globes exhibiting the constellation figures (Class A). The equinoctial colure is

seldom labeled, but on at least two globes it is termed *dāʾirat al-mayl* or *dāʾirat mayl* (declination circle).[20]

The name of the equinoctial colure in Arabic reflects one of the two terms used for the measurement of coordinates of a celestial body in a celestial equatorial system. *Mayl* (declination) is the star's angular distance in degrees north or south of the celestial equator measured along a great circle passing through the equatorial poles and the star in question. This circle is today called a meridian or hour circle. On Islamicate celestial globes any great circle passing through the celestial poles is called a *dāʾirat al-mayl* (plural *dawāʾir muyūl*; declination circle). This is a circle along which the declination is measured, as distinguished from the *madārāt muyūl* (circles [parallels] of declination), which are circles parallel with the celestial equator.[21]

The Arabic term *baᶜd* (distance) refers to the measurement along the celestial equator from the vernal equinox to the point of intersection of the meridian passing through the star (right ascension in modern terminology). This system of celestial equatorial coordinates was known in the Islamic world, as well as to earlier Greek astronomers. Islamic astronomers made use of such coordinates as early as the ninth century.[22] Another method, which made use of the ecliptic was employed, as was a third system of coordinates based on the altitude and zenith, which will be described in connection with the rings attached to the globes (see Figure 31).

From an examination of Islamicate celestial globes we can confirm the preference for the ecliptic coordinate system in which the celestial latitude (called *ᶜarḍ*) was measured north or south from the ecliptic along a great circle passing through the ecliptic poles and the object. The celestial longitude (*ṭūl*) was measured from the vernal equinox eastward along the ecliptic. It is in terms of the ecliptic coordinates that the positions of stars are given in all the star catalogs from Ptolemy's in the second century through that of Ulugh Bēg in the sixteenth century.

In addition to the great circles, several lesser circles often appear on extant globes, though no mention is made of such circles in the Islamicate literature surveyed in Chapter 1. The lesser circles are called *madārāt* (singular, *madār*) to distinguish them from great circles called *dawāʾir* (singular, *dāʾirah*) both terms are from the same root and mean "circle." One globe (No. 94), however, employs the term *dāʾirah ṣaghīrah* (small circle) for the lesser circles.

The lesser circles of the tropics, placed about 23½° north and south of the celestial equator, as well as the equatorial polar circles, are frequently found on globes of the first two classes, and these four lesser circles appear on *all* the globes of the third class that were examined. There are two equatorial polar circles, one north and one south, with a celestial equatorial pole as center and passing through the corresponding ecliptic pole about 23½° distant. These polar circles are labeled *madār quṭb muᶜaddil al-nahār shamālī* (*janūbī*) (circle of the north [or south] pole of the equator). The Tropic of Capricorn is usually called *madār raʾs al-jadī* (the circle of the start [head] of Capricorn), but occasionally the phrase *madār awwal jadī* (circle of the beginning of Capricorn) is found. The Tropic of Cancer is termed *madār raʾs al-saraṭān* (circle of the start [head] of Cancer) and sometimes *madār awwal saraṭān* (circle of the beginning of Cancer). One globe (No. 94) uses for the Tropics an expression of mixed Persian and Arabic, *dāʾirah saghīrah az madār raʾs saraṭān* (*jadī*) (small circle belonging to the circle of the start of Cancer [or Capricorn]), and similarly for the polar circle *dāʾirah saghīrah az madār quṭb* (small circle belonging to the circle of the pole).

Several globes of all three classes have additional circles parallel to the equator at about 12° and 20° on either side of the celestial equator. The two lesser circles to the north are occasionally labeled *madār awwal thawr wa sunbulah* (the circle of the beginning of Taurus and Virgo) at 12° and *madār awwal jawzāʾ wa asad* (the circle of the beginning of Gemini and Leo) at 20°. To the south are the circle of the beginning of Scorpio and Pisces, and the circle of the beginning of Aquarius and Sagittarius. In a few instances only one of the sets of additional lesser

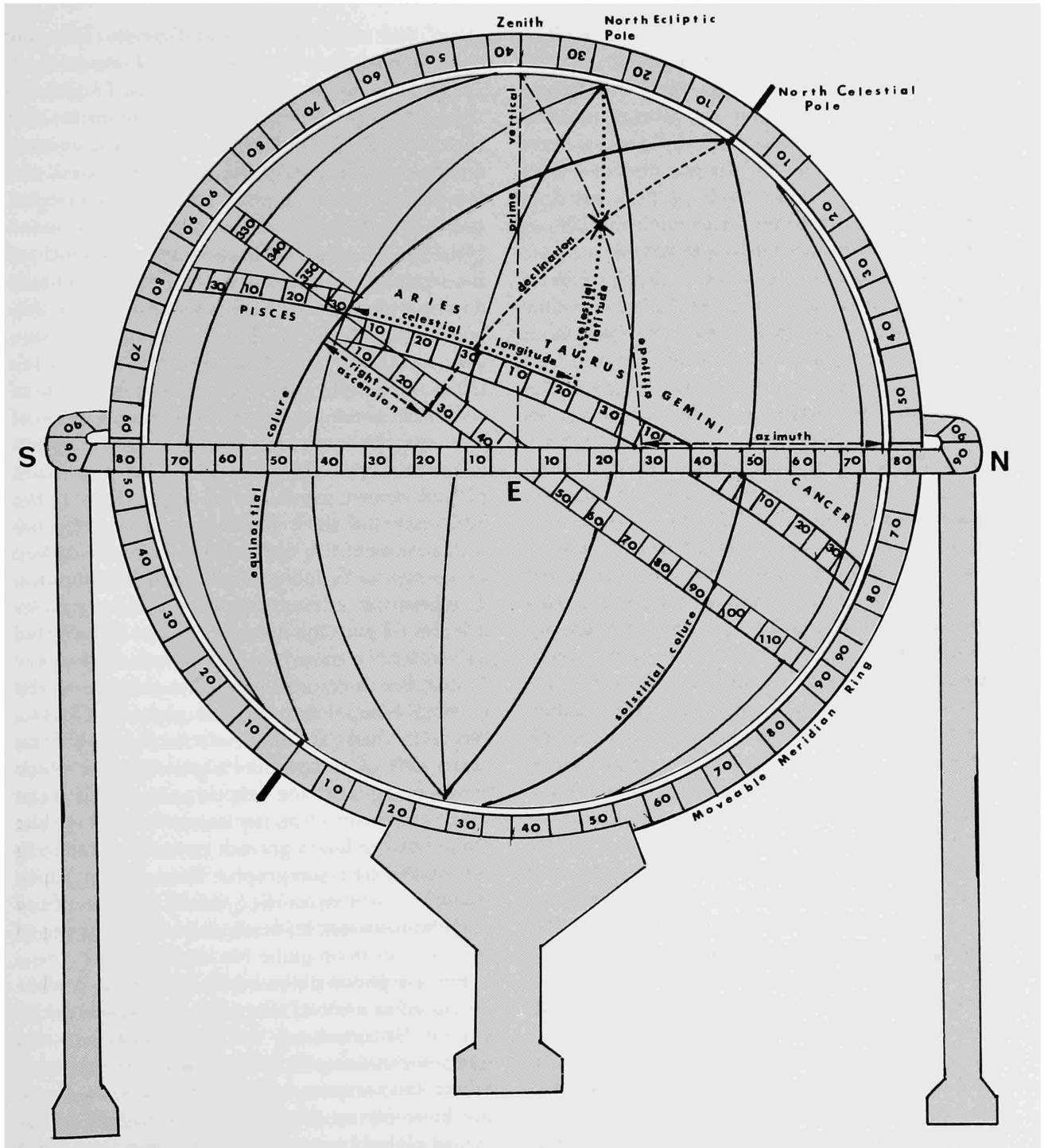



FIGURE 31.—Schematic drawing of Islamicate celestial globe set into meridian and horizon ring assembly, with indications of the three coordinate systems.

circles is indicated, usually at 12°. On a globe (No. 63, illustrated in Figure 20) made in 1603 for Shāh ᶜAbbās I, the lesser circles at 12° to either side of the equator are labeled *madārāt muyūl* (circles of declination), the general term for lesser circles parallel to the equator. This globe does not have the circles at 20°, but does have a set of comparable lesser circles at 12° on either side of and parallel to the ecliptic.

The ecliptic equivalent of the Tropics (circles parallel to the ecliptic and about 23½° on either side of it) were commonly drawn on those globes having no stars, and occasionally indicated on those of Class B, but seem never to have been placed on Class A globes. The ecliptic tropic circles do not appear to bear a particular term on the globes, but, when labeled, have only the generic term for all circles parallel to the ecliptic, *madārāt ᶜurūḍ* (circles of latitude). This term is also applied to the circles parallel to and at 12° from the ecliptic on globe No. 63, mentioned above. As for the ecliptic polar circles, they are the two circles, one north and one south, having the ecliptic poles at their centers and passing through the celestial (equatorial) poles. They are actually the paths of the celestial poles as they circle slowly about the poles of the ecliptic in the precessional motion. The ecliptic polar circles (other than the ring on which the signature was sometimes engraved on the southern hemisphere) appear most frequently on the globes having no stars (Class C), but are known to occur occasionally on the other two types as well. On those globes on which the lesser circles are labeled, the ecliptic polar circles are termed *madār quṭb minṭaqat al-burūj shamālī* (*janūbī*) (the north [or south] circle of the pole of the belt of the houses). In the case of globe No. 94, the label reads *dāʾirah saghīrah az madār quṭb al-burūj shamālī* (*janūbī*) (the small circle of the circle of the pole of the houses).

The full set of eight lesser circles, including the ecliptic and equatorial tropic circles and ecliptic and equatorial polar circles, with one exception are found only on the globes having no stars. They were probably indicated only in order to complete the symmetry and not because all of them had astronomical significance. The one exception, a Class B globe (No. 72, made in AD 1800–1801 by Muḥammad Ashrāf Tūqādī Zādah), has the full set of eight lesser circles and the circles at 12° and 20° parallel to the equator and to the ecliptic all prominently indicated, and in addition has a complete set of parallel circles, marked by very fine ink lines on the wooden globe, at 2° intervals both north and south of the equator and north and south of the ecliptic. Another globe (No. 81, illustrated in Figure 22), probably made in Yazd in the seventeenth century, has a complete set of parallels at 5° intervals from the ecliptic. A most curious network of circles occurs on an anonymous Class B globe of painted paper over a wooden core (No. 76, illustrated in Figure 28). This globe has a network of half drawn great circles originating at the intersection of the celestial equator and the solstitial colure at the winter solstice and extending to the equinoctial colure, marked at 5° intervals. The hemisphere thus defined is also covered by a series of parallels (parallel to the equinoctial colure) drawn in red at 1° intervals, with every 5° parallel drawn in black. The purpose of the network is unknown. On one globe of Class C, No. 112, there are lesser circles about 43° on either side of and parallel to the equator which are also tangent to the ecliptic polar circles at the solstitial colures. The circles are labeled on the globe but the labels are not entirely readable in the published photograph. They appear to be *madār . . . ᶜarḍ sh*[*amālī*] (*j*[*anūbī*]) (circle of . . . [47?] latitude north [or south]). A similar set of circles appears on globe No. 108.

For a celestial globe to be functional it must be placed in a set of rings, usually supported by a stand. Unfortunately the majority of rings and stands are missing today, or are modern replacements, but we have a sufficient number to know the basic forms. Slightly over one-third of the extant globes have one or more rings that could reasonably be considered contemporary with the globe.[23] A close fitting meridian ring (*dāʾirat nisf al-nahār*) was placed about the globe and attached to it at the celestial or equatorial poles. The name means "circle of midday," a term

properly referring only to the upper half of the ring, for the lower half indicated midnight (*nisf al-layl*). A meridian ring is always at right angles to the horizon ring and passes through the north-south celestial poles. Thus it is known as a prime meridian. The globe can then rotate within the ring, pivoting on the celestial poles.

Meridian rings are of two basic types, depending on whether the ring has only one set of holes that are attached permanently to the celestial poles of the globe or whether there are several sets of holes in the ring in which the axis of the globe can be set. In the first type of ring, the meridian ring will rotate with the globe as it is adjusted for different geographical latitudes. The meridian ring of the first type was graduated in a manner that essentially divided it into four quarter circles bearing *abjad* numerals indicating the graduations on each of these 90° arcs. The numerals were nearly always placed so that they increased from the celestial pole,[24] which served as the 0° point, to the point on the ring alongside the celestial equator marked 90° (see Figure 30). The meridian ring was graduated and labeled in the same manner and with the same scale as the ecliptic and equator of the globe to which the ring was attached. There are very few exceptions to this rule. Two globes (Nos. 33 and 54, illustrated in Figures 24 and 25), both nineteenth-century Indo-Persian products probably from the same workshop, having a sliding 6° graduated scale that can move along one half of the meridian ring (from pole to pole) to measure celestial positions and mark them for comparison with other positions.

The second type of meridian ring remained stationary with the 90° points of the non-consecutive numbering of the quadrants at the top (zenith) and bottom (nadir). The axis of the globe was then changed to one of the sets of holes for the required terrestrial latitude. Four extant rings have holes at regular intervals: the instrument maker Jaᶜfar ibn ᶜUmar ibn Dawlatshāh of Kirmān (No. 7, illustrated in Figure 9; the upper half of the ring was detachable and is now lost) and his son Muḥammad ibn Jaᶜfar (No. 62, illustrated in Figure 10) placed holes at 10° intervals and 5° intervals, respectively, while Luṭf Allāh (No. 67) drilled holes every four degrees, and an anonymous Class C globe (No. 110) has holes at 10° intervals.

There are five extant stationary rings from all three classes (Nos. 18, 40, 86, 89, and 114) that have holes drilled at certain specified latitudes.[25] On all but one (No. 18) not only are the graduations labeled alongside the ring, but each hole bears a special label on the outside face of the ring giving the latitude in *abjad* numerals. All of these rings are with globes that are apparently seamless cast objects from Indo-Persia, probably all from the seventeenth-century Lahore workshop; on all of them the northern latitude of 32° (that of Lahore) is indicated. The only signed globe with one of these rings (No. 18) is by Ḍiyāᵓ al-Dīn Muḥammad and is illustrated in Figure 15 (the photograph shows the ring incorrectly mounted on the globe). Figure 32 shows in diagram form two such stationary rings, the more sophisticated version having a rotating arc that is attached at the zenith point by a pin around which it can pivot. The 90° arc is graduated and can be used to measure altitude. On all three extant rings of this form (Nos. 18, 86, and 89), the lower half of the ring is twice as thick as the upper half to allow this arc to rotate. The meridian ring itself is held stationary by two lips at the zero points, by which it rests immobile on the supporting horizon ring. On one globe (No. 89) the outside radius of the top half of the ring is greater than that of the lower half. When the ring is in the correct position, the axis of the globe could be adjusted by setting the north pole of the globe at the desired set of holes in the upper righthand quadrant (as seen in Figure 32) for the corresponding northern geographical latitude and at a hole in the lower right hand quadrant for a southern geographical latitude. A simpler form of stationary ring that is not designed to accommodate a rotating arc is also illustrated in Figure 32. Three of the extant stationary rings give settings for southern latitudes of 18°, 24°, 29°, 34° or 35°, and 72°, while one (No. 18) has a hole at every 5° interval for the southern latitudes and one (No. 40) has

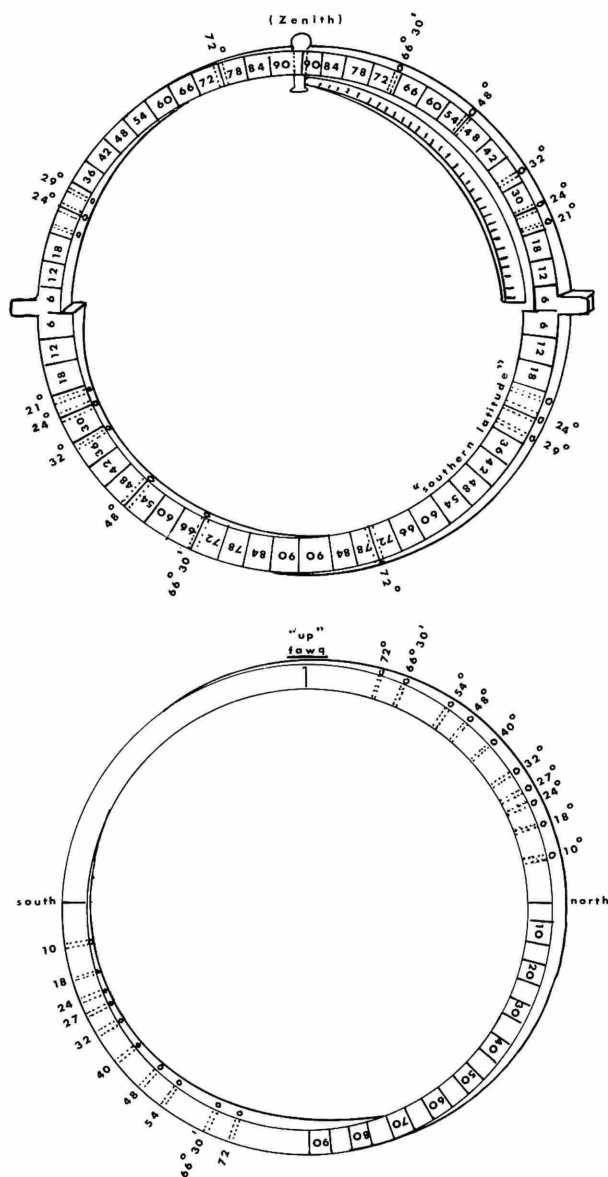



FIGURE 32.—Two examples of stationary meridian rings based on globes No. 40 and No. 86.

no perforations for such settings. There would be little need for such settings, and in fact in some of the rings the pins do not move freely through all these holes. The northern holes show more variation, but always included the one for Lahore (32°) and nearly always one labeled 66° 30′, which is the colatitude of the northern tropic and the parallel at which the longest possible day occurs. This is also the arctic circle and was generally considered the northern limit of the inhabited world on account of the intense cold. Life was thought to disappear at a southern latitude of 21° to 24° because of the heat.[26]

The meridian ring in turn rests in another ring at right angles to it called *dāʾirat ufq* (horizon ring), which is held horizontally in a stand, though one globe of Class A (No. 5) was designed to be suspended rather than attached to a stand. The horizon ring is also graduated and labeled in *abjad* numerals. For Classes A and B the graduations are usually marked by single degrees with every fifth labeled, though other patterns occur just as on the meridian rings and celestial equators and ecliptics.

The horizon rings in Classes A and B frequently have the four cardinal points marked on them, and the graduations are numbered in segments of 90°, each beginning at the east-west points and ending at the north-south points, which also contain the notches for the insertion of the meridian ring (see Figure 33). In Class C globes the horizon rings usually lack the names of the directions of the compass, and the sequences of the numbering tends to be reversed.

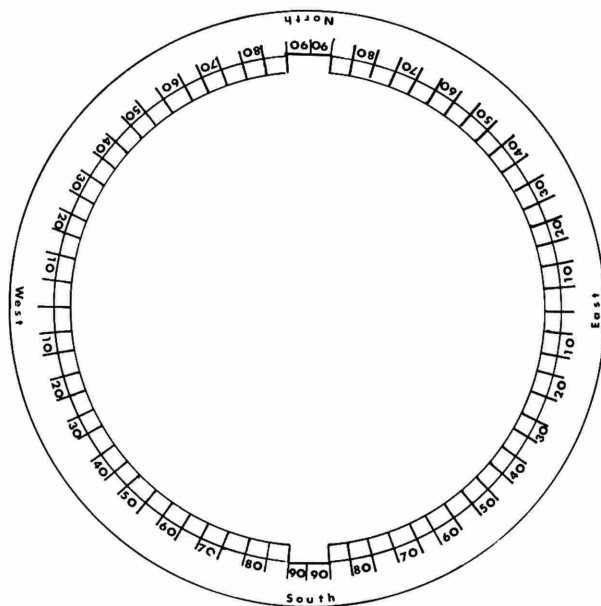



FIGURE 33.—Design of the horizon ring as seen from above.

On such rings, the notches holding the meridian ring serve as the zero points and the numbering proceeds in both directions from these two points (see Chapter 7 for the distribution of these characteristics).

A few horizon rings also align the four cardinal points with the seasons (east-spring, north-summer, etc.), and occasionally the zodiacal signs are named around the horizon ring, placing the division between Aries and Pisces (vernal equinox) at the point marked east, the summer solstice (Gemini-Cancer) at north, and so forth. Three globes give the names of cities along the outer edge of the horizon ring. Globe No. 31 gives 104 cities, and No. 76 (illustrated in Figure 28) gives the names of 72 cities. In the case of the third globe, No. 40, the semicircular ring attached to the underside of the horizon ring and supporting the meridian ring and globe gives the names, latitudes and longitudes of 42 localities, with space left on the horizon ring itself with the indication that it was intended to contain additional names and positions of cities, but in fact no further names were given.[27] The longitudes and latitudes of terrestrial points were measured in antiquity and in the Islamic middle ages by equatorial coordinates. The longitudes were measured from the Fortunate Islands, today called the Canary Islands, continuing a tradition established by the time of Ptolemy.[28]

A few globes of Classes A and B have horizon rings with notches at the east-west points that would have accommodated another ring at right angles to both the meridian ring and horizon ring. This ring would serve as a zenith ring, for it would always mark the point directly overhead and function as a prime vertical of importance in the horizon system of coordinates. Five globes (Nos. 5, 18, 33, 53, and 70) with contemporary rings have the zenith ring (see Figures 15 and 24 for illustrations of zenith rings).

Many of the celestial globes extant are set within rings that are clearly modern replacements. Such modern rings frequently lack graduations and, in the case of horizon rings, do not always serve to accurately represent the horizon. There are fewer meridian rings that seem to be part of the original apparatus than horizon rings, presumably because of their smaller size.

The horizon ring is supported by a stand that can vary in style, but is of two basic types. The most common stand consists of three or four legs resting on a ring base (sometimes four or eight-lobed) or on a circular plate with a central support to hold the meridian ring and globe (for example, Figure 16), or with one or two semicircular metal arcs attached to the under side of the horizon ring itself to hold the meridian ring and globe (as in Figure 34). The second basic style is a pedestal stand on top of which are one or two semicircular metal arcs supporting the horizon ring and holding the meridian ring from

FIGURE 34.—Globe No. 113, unsigned and undated. This globe has no stars and the unusual feature of a graduated solstitial colure. Paris, private collection. (Photo: Alain Brieux)

below (see Figure 10). Eight-lobed ring bases (Figure 34) and three-legged stands with the legs in an S-shaped or leaf-shaped curve (Figures 15 and 24) are typical of Indo-Persian workshops, while four-legged stands with top, central, and bottom square or hexagonal knobs on each leg are associated with light-weight seamed globes of possibly Persian origin.

One thirteenth-century globe (No. 3) has a stand in which two gnomons are incorporated into the east and west sides of the base, each above a 90° arc that constitutes a leg of the stand. Each arc is graduated by single degrees, with every fifth labeled. The gnomons and scales, which may well be contemporary with the globe, enable the altitude of the sun to be determined. On the stand of globe No. 6 a similar arrangement of gnomons and graduated arcs was probably intended, but the stand as it now exists, does not have the gnomons aligned over the graduated arcs so that they could function as elevation dials. Similar basic designs are seen in the stands of globes No. 4 (probably not contemporary with the globe) and No. 115, though the arcs are ungraduated. Perhaps they are simply unfinished or poor copies of an elevation dial stand by an uncomprehending maker.

A globe placed within a meridian and horizon ring assembly becomes truly functional and can be set at any given geographical latitude by rotating the meridian ring within the horizon ring or changing the axis of the globe in a stationary meridian ring. The globe itself could then be rotated about the celestial equatorial axis to represent the movements of the heavens. On those globes with stars, the stars always visible at a given latitude could easily be determined, as could the risings and settings of certain stars for given times of the year, and other astronomical information.

The meridian and horizon rings, particularly when there was a graduated zenith ring or a meridian ring of the stationary style, could also serve to provide the star positions in terms of yet a third system of coordinates, that of altitude and azimuth (see Figure 31). The altitude (*irtifāʿ*) of a star is its distance above or below the horizon ring measured along a great circle or *dāʾirat irtifāʿ* (altitude circle) perpendicular to the horizon and passing through the star and the *samt al-raʾs* (the direction of the head, or zenith). The point of intersection of this great circle and the horizon was called *samt* (azimuthal point). The azimuth of a star is the angular distance measured from this intersection to either the north or the south point of the horizon ring, whichever is closer. It was known that the complement of the azimuth (which could be read more easily on a horizon ring than the azimuth itself) equaled the distance from the *samt* to the equator, and that the complement of the altitude was the distance to the zenith (called zenith distance today). The one altitude or vertical circle that passes through the two points of intersection of the celestial equator with the horizon was called *dāʾirat awwal al-sumūt* (the circle of the first of the directions; in modern terminology the prime vertical), represented in some globe assemblies by the zenith ring. The one altitude circle that also passes through the two celestial equatorial poles intercepts the horizon at the north-south points and is called *dāʾirat nisf al-nahār* (the circle of midday) and is represented by the meridian ring.

On stationary meridian rings with a rotating 90° arc pivoting around the zenith point (see Figure 32), the altitude of a star position can easily be read from the scale. If the meridian ring is of the stationary type *without* the arc, the globe can be rotated until the star is under the meridian ring and the altitude read directly off the meridian ring. If there is a graduated zenith ring, then a similar procedure can be used to read the altitude directly from the zenith ring, even when the meridian ring is of the rotating style.

One anonymous Class B globe, probably from seventeenth-century Persia (No. 81, illustrated in Figure 22) has the meridian, horizon, and prime vertical circles engraved directly onto the surface of the globe. In this instance they are stationary and are valid for only one latitude. The globe was made for 32°, which is the latitude of Yazd. This same globe also has engraved

and labeled on it a declination circle and a celestial latitude circle passing through the star labeled *ᶜayyūq* (*α Aurigae*, Capella). Such circles marked directly on the surface of a globe are clearly for didactic purposes (as shown in Figure 31). The circles can be used to demonstrate the three known systems of coordinates: ecliptical, equatorial, and horizontal. All three of these systems were discussed by Ptolemy, and through the Arabic translations of the *Almagest*, were well-known in the Islamic world.

The most common form of meridian ring was the movable type—that is, one with only two sets of holes by which it was attached permanently to the globe (see Figures 30, 31, and 34). By using the graduations of the meridian ring when it is attached to the celestial poles, the globe can be adjusted (rectified) to correspond to any given terrestrial latitude, and the declination of a star can be read by turning the globe so that the star is alongside the meridian ring, and then reading off the declination from the graduations. The right ascension of the star would be read by finding where the great circle passing through the star and the celestial poles intersected the equator. The meridian ring in this arrangement of the rings is nearly always numbered from the poles.[29] The distance from the star to the celestial poles was probably read directly from the ring and its complement taken for the declination. This particular ordering of the meridian ring graduations has the advantage, however, of allowing easy rectification of the globe to correspond to a given terrestrial latitude simply by placing the corresponding degree of the meridian ring at the north point of the horizon ring, with the north celestial pole above the horizon ring for northern latitude and below for southern latitudes.

While it was customary to mount the meridian ring to the globe at the celestial equatorial poles so as to correctly represent the rotation of the heavens, occasionally holes were drilled at both the celestial and ecliptic poles so that a moveable axis through the globe and the meridian ring could be adjusted to either set of poles. When the meridian ring was set at the ecliptic poles, the celestial latitude could more easily be calculated from the meridian ring and the celestial longitude read from the ecliptic. It was customary to read a celestial longitude within a zodiacal house, such as Taurus 15° rather than 45° from the vernal equinox, which is why the ecliptic is nearly always numbered in twelve 30° segments and always has the names of the zodiacal house written over each segment.

When there is a hole at the ecliptic as well as celestial poles, it would be possible to use a scale such as that described in a chapter appended to the thirteenth-century Spanish translation of Qusṭā ibn Lūqā's tract on the use of celestial globes.[30] This measuring device consisted of a 90° arc whose inner diameter was concentric with the surface of the globe. The quadrant was graduated by single degrees with every fifth labeled. At the end of the arc labeled 90° a thin, well-made nail was attached, which could be easily inserted into one of the ecliptic poles. The arc, which was thus always at right angles to the ecliptic, could be rotated about to read off the celestial longitude and latitude of any star and could be easily removed to permit the globe to turn under the meridian ring. It could be placed in either ecliptic pole depending on whether northern or southern coordinates were required.

When it was not possible to attach the meridian ring to the ecliptic poles of the globe, or to use a measure like that just described, drawing compasses were used to measure the celestial latitude and to compare the distance with the graduations of the equator. (The equator was used rather than the ecliptic since the former was numbered sequentially.) Sometimes a wooden or brass 90° arc, with the same curvature as the globe and calibrated in the same scale as the equator, ecliptic, and rings, was placed over the great circle representing the celestial latitude of the star and the angular distance then read directly from the scale, as al-Khāzinī described in his twelfth-century treatise.

Stationary meridian rings had the advantage of allowing one to easily read the zenith distance and altitude of any star on the globe, while the azimuth would be read from the horizon ring.

For the globes where the adjustment for geographical latitudes was made in the more usual way of rotating the meridian ring along with the globe, altitude could be found using divider compasses, or the 90° graduated moveable arc could be placed on top of the horizon ring and the altitude read from it. One of these two instruments (the divider compasses or the graduated moveable arc) was necessary for reading the distances between stars on the globe.

The utility of the three classes of globes in the Islamic world can be deduced from the treatises on the use of celestial globes, such as that by Qusṭā ibn Lūqā written in the ninth century, and from the form of the extant globes themselves.[31] The globe described by Qusṭā ibn Lūqā differs in basic design from that described by Ptolemy in his *Almagest* (as do all extant globes) even though the treatise was very well known and formed the basis of all star catalogs in the Islamic world.

It is curious that in the literature as surveyed in Chapter 1, we find no reference to celestial globes lacking stars (Class C globes) nor to any attempted constructions of a precession globe of the sort described by Ptolemy. All Islamicate globes having stars, by bearing both an equator and ecliptic are thus made for only a certain epoch. The precession of the equinoxes is sufficiently slow that such a celestial globe (just as an astrolabe) will not be obsolescent for 50–75 years. There is evidence that the globes lacking stars are quite late, and are possibly a Ṣafavid Persian development. While Qusṭā ibn Lūqā described only a globe bearing the major stars on it (Class B) and does not even mention constellation outlines, we can easily see that some of the uses to which he puts celestial globes are readily applicable to all three classes of globes, even those of Class C.

When Class C globes are mounted in meridian and horizon rings they represent a model of the celestial system not subject to precessional change, much as does a simple demonstrational armillary sphere (one lacking the orbits of the moon and planets). Following the treatise by Qusṭā ibn Lūqā (chapters 1–8),[32] it is evident that a globe of this class, though never mentioned by Qusṭā, could be used as a didactic device to demonstrate the following principles: the difference in the positions of the sun for different terrestrial latitudes; the equality of day and night for any latitude when the sun is at one of the equinoxes; the longest and shortest day for any given terrestrial latitude; which latitudes have a six-month night and a six-month day; the latitude at which there are no shadows at certain times of the year; and on what day this last event occurs.

More importantly, a well-made Class C globe could be not only an instructional tool, but a simple means of computing certain information. It should be kept in mind that the measurement of time can be based either on the apparent rotation of a star (sidereal time) or on that of the sun (solar time). Due to the movement of the sun along the ecliptic, the solar day is about four minutes longer than a sidereal day. The procedures for measuring time by means of a celestial globe which are described in the literature, and of which we shall give some examples, in fact measure sidereal rather than solar time. The intervals measured by these methods, however, are no greater than one day, and the difference between the solar and sidereal units could be consequently negligible.

A day can be divided into equal or unequal hours. If the day is considered the length of time required for the apparent rotation of a star and that interval divided into 24 equal hours, the right ascension (angular distance along the celestial equator) could be measured in hours as well as degrees, allowing one hour for 15°. Equal hours were employed primarily for astronomical calculations, while civil and religious time-keeping was based on a system of unequal or temporal hours (*horae temporiae*). In this system the period from sunrise to sunset was considered one-half the day and allotted 12 hours, while the period from sunset to sunrise was also divided into 12. On any day other than the equinoxes the length of an hour of daylight will not equal the length of an hour at night.

By means of a Class C globe having rings, ecliptic, and equator (all of which must be graduated), it is possible to compute the following items: the difference between the length of night

and day for any given terrestrial latitude; the difference in terms of equal hours of the daytime periods of any two days for any given terrestrial latitude; the difference between the daytime period of any given day in two given towns of different latitudes; the length of the hours (unequal hours) for any given day at any given latitude; the latitude of the sun at noon for any terrestrial latitude on any given day; the difference between the maximum elevation of the sun on any one day in two different towns; the altitude of the sun above the horizon for any day at any location given the time of day; the hour of the day (in equal or unequal hours) given the altitude of the sun, the day of the year, and the terrestrial latitude; or the hours of the day given the ascendant (degree of ecliptic at eastern horizon) at a certain location on a given day. Obviously, if the altitude of the sun is known, then the ascendant can be read at the eastern part of the horizon ring, and if the ascendant is known, the altitude of the sun can be measured on the globe for a given day.

The last three items require information such as the time of day or the altitude of the sun, which would have to be read from another instrument, such as a gnomon or quadrant. The position of the sun in the ecliptic could be found from a calendar. To give some specific examples, to find the length of the unequal daytime hour for a given day in a given town, the astronomer would, after rectifying the globe for the given geographical latitude, place the degree of the ecliptic where the sun is on that day on the eastern horizon and then mark the segment of the celestial equator that was also on the eastern horizon. After rotating the globe until the degree of the ecliptic containing the sun is at the western horizon, he would mark the segment of the celestial equator that was at that time at the eastern horizon. By counting the degrees from the first to the second mark along the equator in a west to east direction and dividing the result by 12, the astronomer would then have the length of the unequal hours, allowing 1° per 4 minutes.

If the astronomer wished to know how much time had elapsed (in terms of equal hours) on a certain day given the ascendant and the latitude of the town, then after rectifying the globe for that particular latitude and setting the ascendant (the degree of the ecliptic corresponding with the east horizon) at the east point of the horizon ring, he would mark down the degree of the celestial equator that also falls on the east horizon. Then he turns the degree of the ecliptic corresponding to the position of the sun for that particular day to the east horizon. He notes the degree of the celestial equator that is also now at the east point of the horizon ring. Taking the difference of these two readings and dividing by 15, he finds the number and fractions of hours which have elapsed.

Given the time elapsed (in either equal or unequal hours) for a particular day, or the altitude of the sun at a given location, the ascendant could also be found. This was of considerable interest to astrologers, for once the ascendant was known, then other positions along the ecliptic that were employed in astrological horoscopes could be very easily read from a celestial globe. When the degree of the ascendant was at the eastern horizon (placed in Locus I of the horoscope) the descendant (Locus VII) equaled the degree of the ecliptic coinciding with the western horizon. The "middle of the heaven" (Locus X) is the point of the ecliptic at the upper half of the meridian ring, and the "peg of the earth" (Locus IV), the part of the ecliptic coinciding with the lower half of the meridian ring. After rotating the globe 30° from the initial position of ascendant at the east horizon, Locus II can be read at the east part of the horizon ring, Locus XI at the northern half of the horizon ring, Locus VIII at the western horizon, and Locus V at the lower meridian ring. Then by rotating the globe eastward 60°, Loci XII, IX, VI, and III could be read at the same four locations, respectively. In an older and more complex system, the four initial Loci were determined in the same manner as just described. The other positions along the ecliptic for the other eight Loci were determined by finding the length of the unequal daytime hours for the particular day and then rotating the ascendant to the eighth hour (roughly 120°) and reading Locus II at the northern culmination of the ecliptic and Locus

VIII at the southern culmination; then rotating it to the tenth hour (roughly 30° further westward) and reading Loci III and IX in the same manner; and then rotating the descendant to the second hour (roughly another 60° westward) for Loci V and XI, and the descendant to the fourth hour (about an additional 30°) for Loci VI and XII.[33] In this manner the celestial globe, like the astrolabe, allows astrologers to read directly the degree of the ecliptic for the 12 positions of a horoscope, thus enabling them to avoid complicated calculations.

The celestial globes that have stars are able to do all of the things that Class C globes can do, in addition to a considerable number of demonstrations and calculations involving the stars. Such globes, with the meridian and horizon rings, can be used to demonstrate quite effectively the differences in the apparent motion and visibility of stars, as well as the sun for different geographical latitudes, and at what latitudes the stars never rise or set, since the horizon ring divides the upper (visible) part of the heavens from the lower (invisible) part. They can also be used to demonstrate the daytime path of any star depicted on the globe as well as the rising and setting of each fixed star in any given geographical latitude.

There is no significant difference in the function of celestial globes of Classes A and B, the only difference being that those of Class A present a fuller notion of the asterisms, depict the convenient and familiar pattern of the constellation outlines, and are generally larger and so allow for greater precision than do those of Class B. In addition to the computations discussed for Class C globes, all of which can be done with Class A and B globes as well, the celestial longitudes and latitudes, the declination and right ascension, and the altitude, zenith distance, and azimuth for any star on the globe at any given geographical latitude can be found. An astronomer may calculate the distance between any two stars on the globe, the distance for any given location between two points on the horizon where any two stars rise, the maximum elevation of each star on the globe for any given town, the azimuth of the direction of prayer (*qiblah*)[34] for any given town. If the altitude of any star not on the globe, or planet or moon, is known, as well as the altitude of a nearby star appearing on the globe, then an approximation of the other coordinates can be found from the globe. The hour (in equal hours) that any star on the globe rises could be computed for any given latitude by setting the star at the east horizon (once the globe had been rectified for the given geographical latitude) and noting the segment of the equator at the eastern horizon. Then by rotating the sun to the eastern horizon (or, if the star rises at night, rotating the globe until the nadir of the sun is at the east point) and noting the degree of the celestial equator at the horizon, the hour can be found by counting the degrees between the two readings and dividing by 15. The twilight period was considered to occur when the sun was between 6° and 18° below the horizon. At the end of twilight all stars visible to the naked eye could be seen. In this way one hour and 12 minutes (equal hours) after the sun has set all stars would be visible that were above the horizon ring when the degree of the ecliptic containing the sun was set at 18° below the western edge of the horizon ring.

The celestial globe (No. 3) made by Qayṣar ibn Abī al-Qāsim ibn Musāfir al-Ashrafī al-Ḥanafī for the nephew of Saladin in 622 H/AD 1225–1226 is especially interesting. Incorporated into the quadruped metal stand are two gnomons on the east-west sides, each gnomon being over a graduated 90° arc. By means of these gnomons and graduated arcs, which are essentially altitude dials, the altitude of the sun can be read by the shadow cast by the gnomon on the dial. A somewhat similar arrangement seems to have been intended on globe No. 6, stated to be by Muḥammad ibn Maḥmūd al-Ṭabarī and dated 684 H/AD 1285–1286. After obtaining from a calendar the position for that day of the sun along the ecliptic, the astronomer can then rectify the globe for the geographical latitude of the town, and set the degree of the ecliptic where the sun is to a position equal to the elevation of the sun; the angular distance from the point on the ecliptic occupied by the sun to the horizon ring equals

the angular distance shown on the gnomon scale, measured either from the east or west side of the meridian ring depending upon the position of the sun as shown by which altitude dial casts a shadow on the scale if the astronomer has oriented the globe toward the north. This done, the hour of the day can be calculated, or the ascendant located. A nice feature of this design is that the gnomons or altitude dials built into the stand of the globe will work equally well at any geographical latitude. To align the position of the sun on the globe with its proper altitude, however, the latitude of the town must be already known and the globe itself rectified accordingly.

Globe No. 5 was made at the end of the thirteenth century by Muḥammad ibn Muᵓyyad al-ᶜUrḍī. It may have had the type of sliding gnomon described by al-Battānī in the ninth century (see Chapter 1 and Figure 5). That is, the zenith ring appears to rotate about the globe and to have a slit running along the upper half through which a needle-like gnomon may have been placed. If the gnomon were kept steady over the spot along the ecliptic where the sun was known to be for that day while the sphere was rotated until the shadow cast by the gnomon was as small as possible, then the resulting position of the globe would indicate the altitude of the sun at that moment.

It is in fact theoretically possible to use any celestial globe as a spherical elevation or altitude dial if the astronomer has a thin, portable gnomon.[35] After the globe is rectified for the geographical latitude and the north point of the horizon ring made to point north, if a small gnomon or pin is placed at the position of the sun in the ecliptic for that given day and placed perpendicular to the surface of the globe at that point, then the globe is rotated east or west until the shadow of the gnomon is as narrow as possible. When the globe is in this position the sun's point on the ecliptic is at the same altitude with respect to the horizon ring as the sun is in terms of the observer's horizon. And of course, once the altitude is obtained, other information such as the time of day can be determined. In this way the entire celestial globe could be used, in conjunction with a thin portable gnomon and compass (to tell the direction of the earth's axis) as a spherical elevation dial to determine the altitude of the sun on a given day at a given latitude.

To perform any operations with a celestial globe other than the merely didactic ones of demonstrating the longest and shortest days, which stars are visible at a given latitude, or similar celestial phenomena, the astronomer needed to know the position of the sun in the ecliptic, which required the use of a calendar (a calendar was similarly required for the astronomer to use an astrolabe and was consequently usually inscribed on the back of the astrolabe). Drawing compasses, or a curved graduated arc made especially for the globe, were required to measure some of the coordinates of the sun or stars. If observational instruments were employed together with a celestial globe complete with rings (such as a quadrant to measure altitudes or a gnomon for telling time of day or a portable gnomon, as just mentioned), an even greater amount of astronomical and astrological information could be calculated.

Unlike a planispheric astrolabe, a celestial globe possesses no sighting device. If, however, the use of a carefully constructed celestial globe with stars is supplemented with that of a quadrant and gnomon, then all the astronomical and astrological data accessible by calculation and the use of an astrolabe[36] can also be obtained by means of a celestial globe. The astrolabe, like the celestial globe, is not a direct reading instrument. After making the observation, the astronomer must dial and calculate the desired information. The common planispheric astrolabe can be viewed as a flat representation of a celestial globe, with star positions indicated for only one latitude. A separate plate is required for every latitude.[37]

The planispheric astrolabe has the advantage, however, that the alidade or flat ruler with a sight, which is used to measure the altitude of the sun and stars above the horizon, can also be used to measure the height of mountains or towers or the depth of wells, which of course cannot be done by means of a celestial globe. Moreover, the astrolabe is much more portable

than a celestial globe, and requires fewer supplementary instruments.

As we have indicated, a celestial globe has the advantage to the user of being usable at any geographical latitude, and a large carefully constructed globe allows greater precision in the calculations than does an astrolabe. For the maker a globe, unlike an astrolabe, does not require a knowledge of stereographic projection for its construction.[38] Even though a celestial globe is easier to design, it is more difficult to fabricate from the standpoint of the metalworker. The awkwardness of transporting a globe with stand and the lack of a sighting device clearly mitigated against it being a serious rival of the planispheric astrolabe as an astronomical computing device. Nevertheless, it is clear from the historical evidence that celestial globes were an important part of the equipment of an astronomical observatory and were considered of practical value by astronomers. On one sixteenth-century globe (No. 10, illustrated in Figures 11 and 69) the maker informs us that he made his well-constructed celestial globe with the full set of constellation figures "in a manner useful for the knowledge of all the requirements of astrolabe makers, as an *aide-mémoire* to their craft." It would appear questionable, however, how many of the extant globes of any class were of more than didactic and artistic value to their owners.

The comparison of celestial globes with a common or planispheric astrolabe brings up the question of whether any of the extant celestial globes could also have served as a spherical astrolabe. From the astronomical literature we know that there were spherical astrolabes (*asṭurlāb kurī*) designed to perform the same function as planispheric astrolabes but not requiring for their construction a knowledge of stereographic projection, and allowing for adjustment to different latitudes.[39] It is possible that spherical astrolabes developed along with the planispheric ones, and thus were known by Hellenistic times.[40] It is equally possible, however, from the evidence studied so far, that this type of astrolabe was an Islamic development.[41] What is certain is that the spherical astrolabe was never as popular as the planispheric variety, and in fact only two are known to exist today: one made by an otherwise unknown maker, Mūsā, 855 H/AD 1480–1481, now at the Museum of the History of Science, Oxford,[42] and the other unsigned and undated but made for use in Tunis (possibly sixteenth century), now in a private collection.[43] Qusṭā ibn Lūqā may possibly have written the earliest known treatise on the spherical astrolabe, in addition to his tract on celestial globes.

The two extant spherical astrolabes and those described in the treatises, while differing in particulars of style, consist basically of a sphere (made in two hemispheres) on which are marked the circle of the horizon, circles of equal altitudes (almucantars, at regular intervals from the horizon line), vertical (altitude) circles, hour lines for reading unequal hours, and a series of holes for adjustment to different latitudes. Over this sphere is placed a rotatable cap (the *rete*) of open metalwork, which represents the ecliptic, the celestial equator, some star positions north of the ecliptic, a graduated vertical quadrant with sliding gnomon for measuring solar altitudes, and some type of sighting arrangement for stellar observations.

Clearly none of the extant celestial globes could have served as part of such a spherical astrolabe, for *all* (including those of Class C) have the ecliptic drawn directly on them, and none have almucantars, hour lines, or holes bored in them for various geographical latitude adjustments.[44] Only one has a horizon line indicated (No. 81, see Figure 22), but it is drawn over the ecliptic and the celestial equator, making it stationary for the latitude 32°. While it has a full set of parallels, they are at 5° intervals from the ecliptic rather than from the horizon line. This one globe was clearly designed only for instructional purposes.

P. Tannery[45] has suggested that the hemispherical sundial could have given rise to the concept of a celestial globe bearing the major stars over which there was placed a hemispheric "spider" or *rete* carrying horizon and hour lines. Professor D.J. de Solla Price[46] extends this ar-

gument and suggests that there might have been two types of spherical astrolabes, just as we know there were two types of planispheric astrolabes. The classic form of a planispheric astrolabe consists of a *rete* depicting the ecliptic and major stars that turns over a plate, with the stereographic projection of the almucantars concentric with the observer's zenith and the vertical circles above the horizon. The early type (derived from the astrolabic or anaphoric clock, of which we have fragments dating from the first century AD)[47] is composed of a solid disc inscribed with stars and the ecliptic, which revolved behind an open *rete* showing the hour-lines, the horizon and almucantars, and vertical circles. Parallel with these two styles of planispheric astrolabes, Price postulates that in addition to the classical form of spherical astrolabe described earlier, there might have been a second type composed of a sphere on which the major "astrolabe" stars, the ecliptic, celestial equator, and at least two great circles passing through the celestial poles (i.e., the equinoctial and solstitial colures) were marked. The rotating cap (*rete*) would consist of the horizon lines, a series of almucantars (and vertical circles?), and hour lines for the unequal hours. The rotating cap would require a series of holes or a slot, by which it could be attached to the celestial poles of the globe and adjusted to different terrestrial latitudes. It would also need a sighting device.[48]

Such a concept of a spherical astrolabe suggests the use of a Class B celestial globe as a base. If any of these globes could have been used in this manner we must assume that all the *retes* have been lost from all the extant examples. This is not an unreasonable assumption, since of the two classic spherical astrolabes, one has lost the *rete*. It is true that such a spherical astrolabe is not known from the published treatises, but this omission does not by itself rule out the possibility that such existed. We have a good many Class C globes, which are not mentioned in any known accounts of celestial globes.

There are certain factors that mitigate against this otherwise appealing theory for the use of celestial globes. Although Quṣtā ibn Lūqā described a globe having only the major stars represented, he nowhere mentions using it as a base for a spherical astrolabe. Secondly, of the 28 globes[49] in the category having the major stars and no constellation figures, 15 have one or both rings that are probably contemporary with the globe. One (No. 72) has the maker's signature on the stand and horizon ring as well as the globe itself (see Figures 10 (No. 62) and 28 (No. 76) for other examples of contemporary globes and rings). In these cases it is fairly certain that the sphere was intended as a celestial globe and not as a base for a spherical astrolabe. Since the stand and rings are more easily lost than the sphere itself, it is not at all surprising that the remaining 13 either have none or have replacements. Furthermore, more than half of the globes of this class have both the equatorial tropic and polar circles, with some also having ecliptic tropic circles or ecliptic polar circles, whose function is unexplained when considered as a base for a spherical astrolabe (see the tables following the catalog for the distribution of characteristics). All but one (No. 72) of the globes have the six great circles passing through the ecliptic poles (ecliptic latitude circles) which include the solstitial colure. Only eight globes have the equinoctial colure, and these eight are all among the group having tropic and polar circles. One globe (No. 59) has a hole only at the ecliptic poles and could not take a cap mounted at the equatorial poles.

It is difficult to see how any of the globes of this sort could easily have functioned as a base for a spherical astrolabe. Moreover, on those examined, there are no visible signs of a cap having been rotated over the surface of the sphere. It is significant that in the preface to his tenth-century tract,[50] al-Nayrīzī draws several comparisons between the celestial globe with stand and the spherical astrolabe. He argues for the superiority of the astrolabe. He never mentions using a celestial globe as a base for a spherical astrolabe, as one might expect if the idea were at all current in his day. Nonetheless, the theory is intriguing, and warrants further investigation into the written sources concerning both instruments. It is certainly possible that some of

the celestial globes were used for purposes other than those outlined by Qusṭā ibn Lūqā or al-Khāzinī.

In addition to the matter of stars represented, there are differences in the design of the three classes, in such matters as the representation of lesser circles which occur more frequently on Class B globes than on Class A globes and are universally present on those of Class C. Class A globes, in addition to being generally larger and for that reason more accurate, are frequently constructed more precisely than those of Class B, and certainly more so than those of Class C. For example, on Class C globes, the graduations are usually carelessly executed. These differences between the classes of extant Islamicate globes no doubt indicate different intended uses for the globes, some of which are not apparent from the written sources or extant artifacts.

There are five globes in the catalog that do not fit easily into this categorization. Globe No. 63 (Figure 20), made in 1012 H/AD 1603–1604 for Shāh ᶜAbbās I, the Ṣafavid ruler of Persia, and globes No. 82 and No. 83 each has a selection of stars that technically places it in Class B. Each also has 12 medallions containing the zodiacal signs represented by emblematic motifs that are to be found on other examples of Islamicate metalwork,[51] as well as the coins issued by the Mughal ruler of India, Jahāngīr, who was a contemporary of Shāh ᶜAbbās I.[52] These illustrations of the 12 zodiacal signs are completely outside the tradition of the diagrammatic illustrations of the zodiacal constellations in treatises such as ᶜAbd al-Raḥmān al-Ṣūfī's influential *Constellations of the Fixed Stars*. None of the designs in these medallions outline asterisms that serve as mnemonic devices for star positions. In fact, there are no stars present in the medallions. There are no planets depicted with the zodiacal figures, as are commonly found in other pieces of metalwork.[53] Leo is a lion standing on all fours with mouth open and tail curled over his back, but with no sun; Virgo a bearded man seated holding a sheaf of wheat and a sickle; Libra a man sitting cross-legged with scales over his shoulders like a yoke; Pisces two curved fish, one above the other; Aries a four-legged animal with what looks like antlers; and Taurus a bull with a hump on his back and a bell around his neck.

On all three globes the stars are inaccurately positioned and are not labeled, in contrast to most Class B globes. They all have ungraduated ecliptic and equator circles (rather rare on celestial globes), and several lesser circles, all of which are labeled. The globe produced for Shāh ᶜAbbās I is the earliest dated globe to have ecliptic tropics indicated on it. It is also unique in having a large crescent moon engraved on it between the north equatorial pole and the House of Aries; the crescent moon is a common motif in decorative Islamicate art.[54] If these three globes had any function other than as *objets d'art*, it would be as a Class C globe, making use of the greater and lesser circles indicated but ignoring the stars. In any case, they represent an artistic style clearly outside the usual Islamicate globe-making tradition.

Globe No. 73 was made in 1221 H/AD 1806 by Muḥammad ᶜAlī al-Ḥusaynī. It also has zodiacal figures. The star positions are slightly more accurate than the preceding three globes, and most of the 50 stars are labeled. Iconographically there are some similarities between the zodiacal figures depicted on it and those on the globe made for Shāh ᶜAbbās I and the two closely related globes. The zodiacal figures of the nineteenth-century *papier mâché* globe, which are not set in medallions although they are still not constellation outlines, also have features in common with the zodiacal figures on globe No. 56. This latter anonymous *papier mâché* globe (see Figure 29) also does not fit into the basic three categories of Islamicate celestial globes.[55] It has a full set of constellation figures painted on it, but has no stars at all. The constellation figures are not asterism outlines and seem to represent yet another iconographic tradition.[56]

Of the 126 Islamicate known celestial globes, all are hollow metal globes except seven (Nos. 36, 56, 72, 73, 76, 93, 94). These are either painted wood or wooden cores with *papier mâché* covering, which is painted and lacquered (see Figures 19, 27, 28, and 29).

Textual evidence for the different methods employed in the construction of the sphere itself is fairly meagre. In the *Almagest* Ptolemy speaks only of a solid sphere, but gives no details as to the material or methods used to form it.[57] Leontius (see Chapter 1) in the seventh century says simply that if the sphere is of wood it is to be stained, and it is to be smoothed over with plaster or wax to fill any cracks; when dry it is to be painted a deep azure blue. He gives no specific information on how it is to be fashioned, whether it is solid or hollow, whether in one or more pieces, or whether it was smoothed and shaped on a lathe. He does seem to imply that it might be made of something other than wood. At the end of the ninth century, al-Battānī supplies little information on the actual construction of the sphere, only saying that it should be of copper (*nuḥās*) and turned on a lathe (*makhrūṭah fī al-shihr*). Qusṭā ibn Lūqā gives no directions for the construction of the sphere or the rings, although when mentioning the placement of the globe in the horizon ring he does refer to it as "the stone."[58]

For more detailed information on the process of construction we must turn to the Spanish translation of Qusṭā ibn Lūqā's treatise, prepared for the king of Castile, Alfonso X of Seville. Because the original treatise contained nothing on construction, King Alfonso directed that a section be added on the materials and processes employed in the construction of celestial globes. Thus the first four chapters,[59] written between AD 1276 and 1279, provide detailed information that may reflect practices prevalent in the thirteenth century and earlier in Spain, in other western parts of the Islamic world, and possibly elsewhere. The treatise states that the sphere might be made of any of several materials all of which, except for wood, are discounted as being deficient. Gold and silver are too expensive, heavy, and easily bent; copper, while stronger than gold or silver, is not as maleable and cannot be worked as easily; brass, which he calls *tinto cobre*, is more maleable than copper and stronger than gold or silver, but if a sphere were thick enough not to be bent out of shape easily, it would be too heavy. The author adds, however, that of all metals this is best. Iron would be too heavy and rust too easily, while tin would bend easily if thin and be too heavy if sufficiently thick. The same arguments apply to lead, which has the additional problem of turning black and destroying the constellation outlines and having to be cleaned by scraping. The author then mentions *ceni*,[60] an alloy used by the Arabs for basins and other household objects, which is too brittle. Another alloy, *fuslera*, requires smelting and is unserviceable for a sphere. Stone is dismissed as being too heavy and if of the transparent type (?quartz) the constellations could not be easily seen. Clay globes would break and figures could not be made on them (a rather curious statement since pottery was easily decorated), and would be too ignoble a material for such a noble object. Leather could not be shaped sufficiently nor retain its shape for long, and would shrivel in heat. Cloth and parchment would shrivel or stretch with the weather and in the end be worthless. Thus wood is, in the author's view, the optimal material.

According to the compiler, the wood selected must be of a kind that will warp, split, and rot the least. For this reason it must be gathered when the moon is waning in the last days of the lunar month. Immediately after gathering, it must be soaked in hot water for two or three days and then placed in sunlight to test for warping or splitting. If the wood neither warps nor splits, the artisan may proceed in one of two ways, depending on whether a solid or hollow sphere is desired. If the globe is to be solid, the artisan then makes the piece as round as possible while keeping it slightly larger than the intended finished product. After marking the two points he intends to use as poles, he places those points on the two ends of a lathe. Then with a steady hand and using a wide cutting edge made of good steel with a thin, very sharp edge, he turns the lathe and evenly removes from the surface of the wood the desired amount to produce a round solid sphere.

If a hollow wooden globe is to be produced, he can either make it from a solid one as just

described or use wooden rings. If the maker chooses to produce the hollow globe from a solid sphere he draws and cuts out a circle on the surface of the sphere, through which he can hollow out the rest of the globe; after that he replaces with glue the circle of wood as a plug and smooths the sphere again on a lathe.

This section of the treatise presents two procedures that can be used for making a hollow wooden globe involving wooden rings. By the first method the carpenter cuts a large number of wooden rings of the same diameter and thickness. Two of them he places at right angles, one inside the other, having notched both rings in such a way that when aligned both the joins are smooth and both rings have the same circumference. Inside these two rings and at right angles to both is placed a smaller wooden ring, whose outside radius equals the inside radius of the two first circles. It is attached to the two original rings by four well-made wooden nails at the four points of contact. From other wooden rings of the same size as the first two, the draftsman then cuts several arcs of varying sizes and shapes, which are attached with wooden nails to the smaller inside ring, thereby providing the remaining surface betwen the two initial rings of the globe. (The author does not describe how these pieces are to be attached to the two original rings. Perhaps it is done by shaping their ends into wedges and glueing together adjacent rings.)

The second method using wooden rings begins by making a large number of wooden rings of diminishing diameters (two of each size). These rings are then stacked with the largest in the middle, graduated to the smallest on either side, thus producing, more or less, a sphere. Both of these methods would produce a frame whose sphericity would depend in large part on the width of the rings.

After the wooden sphere was constructed, it was to be covered with parchment using a very strong glue. After that had set, the sphere was covered with leather of the sort used for shield covers, but cut thinner. The leather was then smoothed until the sphere was very round. Following this, the sphere was covered with a layer of a rather thick plaster called *plastro*, and then plastered again with a thin *gris* (literally, gray). The plaster was then smoothed and the globe tested for sphericity with a pair of dividers.

In the treatise on the spherical astrolabe (*astrolabio redondo*) in the *Libros del Saber*, that draws from Arabic sources, Isaac ben Sid presents another method of constructing a hollow wooden sphere, this time by making two hemispheres.[61] According to his description the maker is to produce four wooden rings of the same size; their thickness will equal the thickness of the wall of the globe. One of the rings should have 12 notches cut in it at 30° intervals, each notch going half-way through the thickness of the ring and all the way through the width of the ring, being wide enough to allow for the width of one of the other rings. A second of the four rings is then cut in half, placing in each end a notch of half the thickness of the ring. At the midpoints of these semi-circles and on opposite sides a notch should be made equal to the breadth and one-half the thickness of the other, so that they can be crossed and meshed over each other. The four notched ends are then placed in the four notches (90° apart) of the first ring. The two remaining rings are each cut into four pieces, and at one end of each a notch equal to one-half the thickness is cut. The other end of each 90° arc is tapered so that they can fit together at the intersection of the two crossed half-circles. Their notched ends are then placed in the remaining eight notches of the first ring, resulting in a frame for a hemisphere with 12 sections formed by wooden arcs attached to the first ring. The intervening spaces are then filled with pieces of wooden rings of equal radius that are placed in each segment, at first dividing it into four parts, then eight, and so on, until eventually the space is closed. The compiler notes that what might have been intended was for the maker to use pieces of rings of decreasing radii and place them in the open segments parallel to the one complete ring, thus stacking and glueing them together in each segment until it was filled.

When two identical hemispheres are made in this manner, they are to be joined together to

form a hollow wooden sphere, in which two holes are then bored at diametrically opposite points. Through these holes a round wooden rod was passed to serve as an axis (*miḥwār*) for the sphere. Such an axis is not used in a spherical astrolabe, which indicates that the compiler may have obtained this method from a work on celestial globes, since they do require an axis about which the globe can pivot. Isaac ben Sid ends by saying that in order to produce a smooth surface, leather from a horse or donkey would be placed over the wooden sphere, and its surface whitened with chalk.

None of the seven extant wooden or *papier mâché* globes has been analyzed as to the precise method of construction so as to compare their construction with these thirteenth-century procedures. To make such an analysis would involve serious alteration of the globe.

The vast majority of extant Islamicate globes are in fact made of metal and appear to be of two basic types: those with an evident seam, and those that appear seamless. Both types are hollow. The treatises on celestial globes are silent on the topic of constructing metal spheres. In the astronomical literature only one passage has been found that describes the production of a metal sphere.[62] This description occurs in the same treatise on the spherical astrolabe compiled by Isaac ben Sid in the thirteenth century for the *Libros del Saber*, where he states that a metal sphere is not as desirable as a wooden one.[63]

In this particular procedure the hollow globe is to be made by joining together two cast hollow hemispheres. Instructions are given to make a mold from a block of hard stone, which obviously must withstand the melting point of alloys, though this is not explicitly stated in the text. The stone block should be larger in breadth than the diameter of the desired globe and have a height greater than the radius. The maker marks the surface with a circle equal to the circumference of the desired globe and then hollows it out (again, the method for doing so is not specified), making it a hollow hemisphere in which one can fit and turn a "form of iron." This was a device for determining when the hemispherical cavity had the correct size and curvature, and it consisted of an iron half-circular plate whose radius is that of the desired globe and that has a handle attached to the flat edge by which it can be held. Then a solid hemispheric mold of clay (*tierra*) is made whose radius is somewhat smaller than the hemispheric cavity in the stone and equal to the inner radius of the finished globe. The maker then pours the molten alloy into the space between the clay and stone molds being careful to fill it to the upper edge of the stone mold; no directions are given for devices to keep the clay mold from falling against the stone mold. When the alloy has cooled the clay inner mold is removed and the completed metal hemisphere removed from the stone mold. By using the "form of iron" and a hammer, any roughness can be removed from the finished casting. The edge of the completed hemispheric shell should then be carefully filed until smooth and even. After a second hemisphere is made in the same manner, a long, thin metal strip of nearly the same length as the circumference of the globe is cut and soldered around the inside edge of one of the hemispheres so that half of its width protrudes above the edge of the hemisphere. When the solder is set, additional solder is applied to the other half of the metal strip and the other hemisphere set down over it. In this way the hemisphere should be held firmly together by the metal band soldered to their inside edges, with no space showing between the edges.

There are roughly 41 extant globes clearly made of hollow metal hemispheres that have been soldered together or perhaps joined by an internal band as suggested in the *Libros del Saber*. On some the soldering is obvious and mars the surface of the globe itself (see No. 7 in Figure 9), while on others it is so neatly executed that the seam is scarcely visible (see No. 81, Figure 22).

The seamless, hollow metal globe is never mentioned in the literature. At least 49 such globes are known, and most are products of Mughal or nineteenth-century India, although there are three possible examples that are earlier and from outside of northwestern India. All such globes are without any apparent seam and have

at least one fairly large and several smaller visible plugs, although on some globes they are difficult to locate (see Figures 11, 12, 18, 25 and 26 for examples of plugs). Suggested methods of constructing hollow metal seamless globes will be discussed below.

Once the sphere itself was constructed, its surface was made as even and smooth as possible by turning on a lathe. In the ninth century al-Battānī specified that it should be turned on a lathe. Many of the extant globes show clear signs of having been polished by this method (see Figure 35) and display the circularity and sphericity characteristic of all carefully turned work.[64] The extant globes of wood or *papier mâché* over wooden cores do not seem to have been as frequently shaped on a lathe (see No. 36, Figure 19; and No. 56, Figure 29), though globes No.

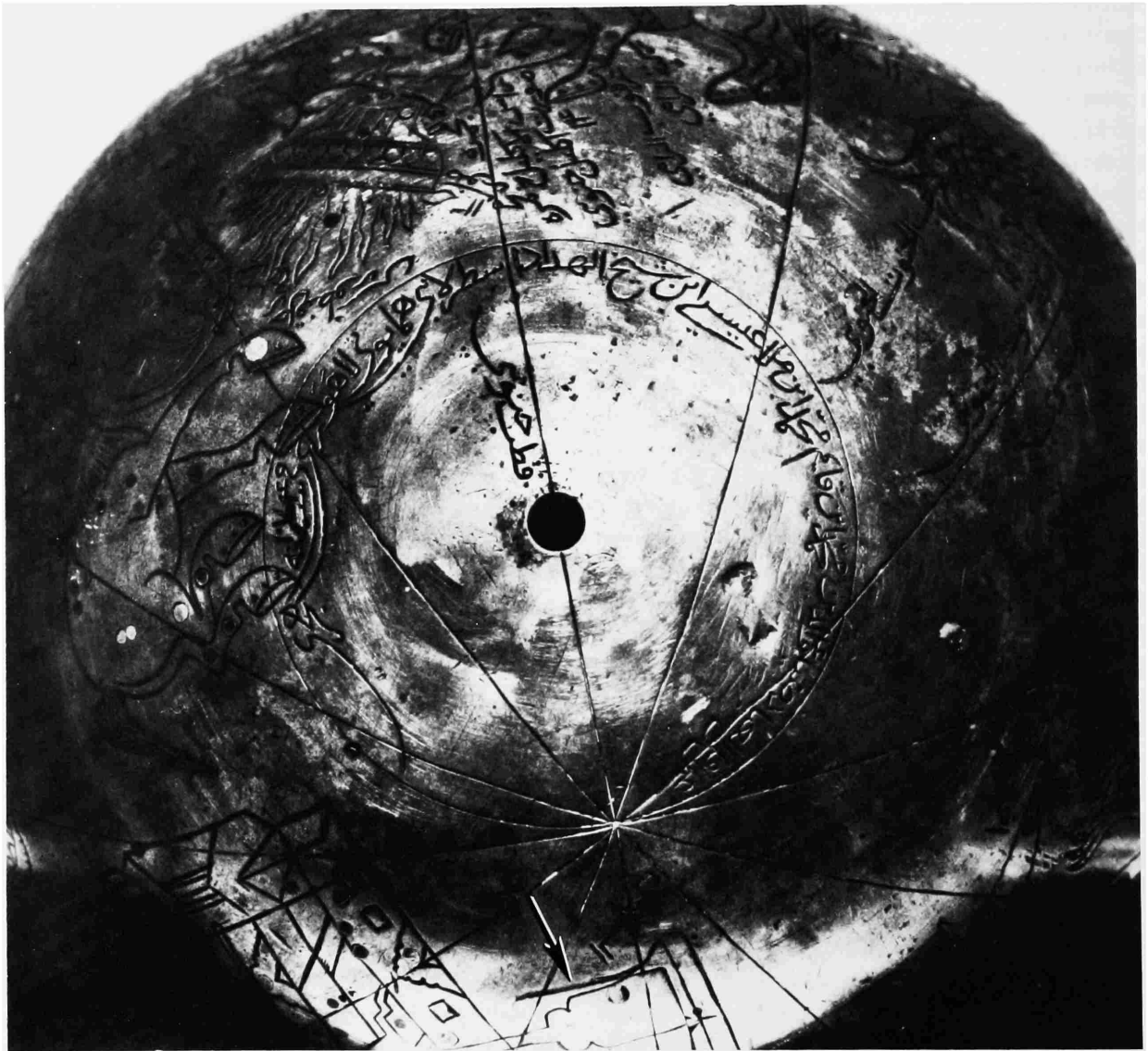



FIGURE 35.—Detail showing signature of maker. Globe No. 27, dated 1024 H/AD 1663–1664, by Ḍiyāʾ al-Dīn Muḥammad of the Lahore workshop. Arrow indicates plug. Royal Scottish Museum, Department of Technology. (Photo: The Royal Scottish Museum)

72 and 76 (illustrated in Figure 28) display better sphericity than the other wooden or *papier mâché* globes.

The maker then proceeded to place upon it the necessary circles, graduations, stars, constellations, and labels as required by his design. According to the procedure outlined by al-Battānī in the ninth century, the maker probably began with drawing or incising on the surface two great circles at right angles to one another, which would represent the celestial equator and solstitial colure.[65] The maker probably divided the equator into four 90° quadrants and graduated and labeled each in order to obtain the scale necessary for the placement of the remaining items. The celestial equator was usually represented by a band which was about 5°–6° wide, one edge of which would represent the line of the equator itself. At an angle of approximately 23½° the great circle representing the ecliptic would be drawn with a lesser parallel circle about 5°–6° away from the line of the ecliptic. The ecliptic would then be graduated in the same scale as that used for the equator. Al-Battānī specified that the star positions were indicated next and that only after the stars were positioned were the five great circles then to be drawn at right angles to the ecliptic at 30° intervals (the sixth great circle being already represented by the solstitial colure). Indeed on some globes (as on the Smithsonian globe, No. 38), it is evident from the engraving that the ecliptic latitude circles were engraved after the stars were positioned, for the engraving of the lines runs through some of the stars and other engraving. Lesser circles could then be indicated if the design called for it; sometimes the lesser circles must have been added after the stars and constellations were placed on the globe, as was the case with the Smithsonian globe where the tropic is only partially drawn since it was incorrectly positioned, probably causing the maker to stop work on a nearly finished globe.

The treatise on the spherical astrolabe included in the thirteenth-century compilation *Libros del Saber* again provides us with some interesting information on the equipment and techniques used to inscribe the circles on a sphere.[66] The compiler described a round compass (*compas redondo*) used for this purpose consisting of a slender band of iron in the form of a 90° arc graduated by single degrees, whose inside diameter is concentric with the outside surface of the sphere. Thus for each globe of the same size there would be a special round compass. A pivot is attached at one end and at the other a moveable marker so as to inscribe all possible circles on the globe. When set at 90° the round compass could be pivoted about the stationary point to inscribe the great circles and when set in other positions could mark the lesser circles.

Also writing in the thirteenth century, the North African astronomer al-Marrākushī gives a method for inscribing great circles at right angles to one another on a sphere. A point is chosen on the sphere, and with it as center a small circle is inscribed around it with a drawing compass. The circle is divided into four equal parts. Then a graduated quadrant of copper (*nuḥās*) especially made to fit that globe is employed. Al-Marrākushī had earlier given a means using drawing compasses for determining the diameter of a sphere once the sphere is made, which was then used to make the meridian and horizon rings and the graduated quadrant. The quadrant was to be placed with one end at the center of the circle on the sphere and should pass through one of the points marking the equal divisions of the circle. The other end of the quadrant would mark one pole. The quadrant was placed in a similar fashion over the opposite point on the small circle, to mark a second pole. Then using these two points as poles, a great circle is inscribed passing through the center of the small circle and the two remaining points on the small circle. Al-Marrākushī says that to inscribe the circle "it is best that you draw it with the instrument of the turning-lathe (*bi-ālat al-kharṭ*)."[67] What is intended by this phrase is not entirely clear, but possibly the sphere would be attached to a lathe at the two poles. Then as the sphere rotated in the lathe, a line could be incised by holding the incising instrument, beginning at one of the two points on the small circle.

After the first great circle is marked on the sphere, then a second one at right angles to it is determined in a similar fashion, placing the quadrant along the other two points on the small circle. Then the ecliptic is to be drawn, but al-Marrākushī gives no value for the obliquity of the ecliptic nor directions for how to place it accurately on the sphere. Al-Battānī in his early treatise supplies more specific information on the determination of the position of the ecliptic (see Chapter 1).

Unfortunately no further information is supplied in written sources about techniques employed in drawing firmly and evenly on spheres, even though we have many details about the practices in Ṣafavid Persia by which the astrolabists were able to incise carefully executed lines on planispheric astrolabes.[68]

On a globe being prepared by or for an astronomer-astrologer (besides Class C globes), the star positions would no doubt have been indicated next, after the great circles on the globe, using dividers to measure the ecliptic coordinates in terms of the equator's scale and to transfer these distances to obtain the star positions on the globe. Al-Battānī again is quite specific about how to determine the star positions accurately on a sphere using dividers or a drawing compass (see Chapter 1 and Figure 4). Some makers probably employed a graduated and labeled 90° arc concentric with the surface of the globe whose base could be placed along the ecliptic and the appropriate longtidue and latitude marked on the globe. Others might have used the 90° graduated arc having a long pin at one end which could be inserted in the ecliptic poles and rotated about, if holes had been drilled at the ecliptic poles.[69] The latter method would have allowed for greater precision in the celestial longitudes of the stars at a distance from the ecliptic. Al-Marrākushī stated that the sphere was to be mounted in the horizon and meridian ring assembly before the star positions were determined. Holes were to be bored at both the ecliptic and equatorial poles, so that by mounting the sphere in the meridian ring at the ecliptic poles the graduated rings could be used to position the stars. Then the globe would be mounted at the celestial poles when ready for use.[70]

The coordinates themselves were obtained, according to the inscriptions on some of the globes, from three star catalogs: that of Ptolemy (compiled for AD 138); that of ᶜAbd al-Raḥmān al-Ṣūfī prepared for the epoch 364 H/AD 974, and that of Ulugh Bēg made for 841 H/AD 1437–1438. It is possible, of course, that other star catalogs were employed by some makers.[71]

Because of the precession of the equinoxes, the globe maker needed to increase by a constant the longitudes given in the star catalog he had chosen to use. Various constants were employed for the precession: Ptolemy had used 1° for every 100 years. Al-Ṣūfī, when changing Ptolemy's longitudes, employed a value of 1° per 66 years, while the thirteenth-century astronomer Naṣīr al-Dīn al-Ṭūsī used 1° per 70 years.[72]

On eight of the extant Islamicate globes the precise increment is given as well as the catalog, so we know precisely what value that particular maker was employing. In 539 H/AD 1144–1145 Yūnus ibn al-Ḥusayn al-Aṣṭurlābī (globe No. 2) based his star positions on the Ptolemaic catalog, increasing the longitudes by 15°18′ which gives a value of 65.8 years per degree. In 622 H/AD 1225–1226 Qayṣar ibn Abi al-Qāsim ibn Musāfir al-Ashrafī al-Ḥanafī (globe No. 3) also used the Ptolemaic catalog, with an increase of 16°46′, corresponding to 64.9 years per degree. Muḥammad ibn Maḥmūd al-Ṭabarī based his globe (No. 6), made in 684 H/AD 1285–1286, on the star catalog of al-Ṣūfī[73] with an increase of 5° in the longtidues, giving a value of 1° every 62.4 years, or 1° per 64 lunar years. This is a surprisingly high ratio, and is yet another slightly irregular feature of this particular globe (see catalog entry and Figure 6). Jaᶜfar ibn ᶜUmar ibn Dawlatshāh al-Kirmānī based his two globes (nos. 7 and 8) on al-Ṣūfī's catalog, as did his son Muḥammad ibn Jaᶜfar (No. 62). Jaᶜfar stated on his globe, dated 764 H/AD 1362–1363, that he used an increment of 6°3′; on the globe dated 785 H/AD 1383–1384 the number of the minutes following the 6° is not legible. His son's globe is dated 834 H/AD 1430–1431, with an increment of 7°5′. The

value employed by father and son is clearly the same, 1° per 64.5 years, or 1° per 66.4 lunar years. With this consistency we can determine the missing amount on the second of Jaᶜfar's globes—that is, the increment should read 6°23′.

Three globes are stated to be based on Ulugh Bēg's star catalog. The most recent of the three is that made in 1112–1113 H/AD 1701 by Riḍwān (No. 31), who does not state an increment in the longitudes over that given by Ulugh Bēg. A globe by Qāᵓim Muḥammad ibn ᶜĪsà ibn Allāhdād Asṭurlābī Lāhūrī Humāyūnī (No. 14), made in 1047 H/AD 1637–1638, is stated to be increased by 3°, giving a value of 1° for every 66.6 years and 1° per 68.7 lunar years. The third globe, which is anonymous (No. 65) was made in 1056 H/AD 1646–1647 and bears an inscription saying the longitudes were increased by 4° over those of the Samarqand observatory. This increment gives a value of 1° per 52.25 years (or 53.75 lunar years), which must surely indicate an error on the part of the maker.

A globe made for a given epoch could be used with a fair amount of accuracy for the better part of a century, which was also the period of usefulness of an astrolabe. The astronomical phenomonon of precession provides a convenient way to approximate the epoch for which an undated globe having stars was made.[74] For this purpose the longitudes of the stars along or very close to the ecliptic can be measured and compared with the same stars on a well-made dated globe or with the star positions in a star catalog. The stars close to the ecliptic are easier to position accurately than those further from the ecliptic. It is indeed difficult to date an object to within less than 50 years by this method, for the limitations of such dating are considerable. Many extant globes have irregular graduations (see Table 3 in Chapter 7), and since the graduations of the equator and ecliptic served as the scale for the positioning of its stars, great accuracy or consistency could not be achieved when the scale itself was irregular. On globes that are precisely graduated, all but two have one degree as the smallest interval. The Smithsonian globe (No. 38) has one-half degree graduations and is so well executed that it is one of the finest examples of precision in this field. One other globe (No. 53) has the ecliptic but not the equator graduated by half-degrees, but it is not available for study. When a maker states on a globe that the increase in star positions was 16°46′ or 6°5′, it by no means implies that he could attain such precision on his globe. The fact that only two globes have graduations smaller than 1° and none of the globes is of sufficient size to cause the degree markings to be widely spaced, makes it quite impossible for star positions to be approximated within less than half a degree. A statement on a globe giving more precise increments in star positions must be interpreted as indicating that the star catalog from which the maker obtained his coordinates was based on such an increase, for the maker of the instrument would be forced to round off all coordinates to the nearest half-degree or, in the case of many globes, to the nearest degree.

Even granting that a globe can be accurate to within half a degree, in the vast majority of cases we do not know the value for precession a given maker would employ, or what catalog we had at his disposal. We cannot work backward from modern values, for such an approach is unhistorical and completely distorts the interpretation. One approach that might prove productive is to compare a series of globes, using some as standards for comparison. In the case of the seventeenth-century Lahore workshop, which generally executed impressively precise globes, the star positions are *identical* on all their products, which among the dated objects range from AD 1622 to 1680. Furthermore, some of the anonymous items, such as the Smithsonian globe (No. 38), have these identical star positions. So we can conclude that all members of this workshop employed the same set of star positions no matter when they were producing the actual object.

On carefully constructed Class A globes after the stars had been indicated (on metal globes most frequently by inlaid silver dots) the constellation outlines would be engraved around the stars based on illustrations such as those in al-

Ṣūfī's treatise on the fixed stars, but with dress and details adapted to local artistic customs. There is indication that on some globes the ecliptic latitude circles and the lesser circles were added last. On Class B globes, of course, the globes were completed once the stars had been indicated and labeled. It is unlikely that the holes of the celestial poles (and ecliptic poles when drilled) were made until after all the circles were drawn on the surface of the globe.

On certain Class A globes that have poorly positioned stars it appears that the constellation outlines were engraved first and the stars then placed within and around these outlines, for the stars sometimes are on top of the lines of engraving. Such globes were probably made by artisans who were not themselves astronomers or professional instrument makers. They may well not have been familiar with the star catalogs and the methods for measuring the coordinates on the surface of the globe, and so executed the constellation figures first and determined the position of the stars in relation to these figures rather than to any coordinate system. Such globes, of course, are sufficiently inaccurate to render them useless for astronomical calculations, though occasionally they are exceptionally attractive.

On the methods of constructing the rings and stand for a celestial globe the literature has little to say. All but one extant set of rings are made of metal, probably cast, and then turned on a lathe for finishing. The one exception is the set of rings for No. 76 (see Figure 28), which is wooden and clearly contemporary with the globe.

In the ninth century al-Battānī described an elaborate set of rings that includes both moveable and stationary meridian rings and a gnomon (see Figure 5). He explains[75] that you must take two rings of copper (*nuḥās*) the same size, of smooth surface and true circularity. The inside diameter of each is to be equal to the diameter of the globe (these rings will be numbers 1 and 2 in Figure 5). Then two rings are to be prepared that fit inside one another—that is, the inside diameter of the smaller will be the diameter of the globe and its width will be one-third the width of the first two rings; the inside diameter of the larger ring will equal the outside diameter of the smaller ring and its width will be two-thirds that of the first two rings. These two rings meshed together (numbers 3 and 4 in Figure 5) will be the size of one of the first two rings. A fifth rings is to be made whose inside diameter equals the outside diameter of the first four rings, for this ring will fit around the other four (number 5 in Figure 5). All the rings are to be divided into four equal quadrants, with each quadrant divided into 18 divisions of 5° each and labeled in *abjad* numerals, numbering each quadrant of 90° so that the 90° labels occur at two opposite places on the ring (that is, in non-consecutive segments of 90°).

The smaller of the two rings that nest together (number 3) is to be perforated (at the zero points) and at these points is to be affixed to the equatorial poles of the globe and fastened from outside the ring with filed nails. The points of attachment on the ring are to be labeled "pole of the north" and "pole of the south." The larger of the two rings to be nested (number 4) is to have notches cut on the outside end at the zero-points; the notches are to be one-half its width and the thickness of the horizon ring. Ring 3, to which the globe is attached is then placed inside ring 4 and the two are encompassed by the horizon ring (number 1), which has notches equal to two-thirds its width on its inside edge at the 90° labels, marked North-South. There are also to be notches on the outside edge of the horizon ring at the zero-points, labeled East-West. The ring number 2, the zenith ring, is also to have four notches, two opposite ones equal to the two outside notches of the horizon ring, and the other two equal to the height of the small ring (number 3) and one-half the height of number 4. Al-Battānī does not specify notches having been made on the outside edge of ring 4, but he must have intended them. The zenith ring (number 3) then overlays the horizon ring and the two meridian rings. The largest ring, number 5, is apparently to have a slot made in it in the middle of its thickness along one of its upper quadrants (the text is slightly obscure here). Al-Battānī says that "we make a piece of four-sided (*murabbaᶜah*)

copper the size of the thickness of the ring and the width of the slot. We incise in its middle a straight line cutting it into two equal halves; we file along the two sides of this line with a file (*bi-l-mibrad*) and make it small at the lower end of the piece like a rounded file."[76] The lower end touches the surface of the sphere and the upper end extends up through the slot in the ring.

The large ring is then fixed to the poles of the meridian and zenith rings by pins. The upper part of the outside rings has a suspensory device of two rings (*ᶜurwah* and *ḥalqah*) like that found on an astrolabe (*dhāt al-ṣafāʾiḥ*). Al-Battānī then concludes his discussion by telling the reader how to use this moveable gnomon (*muwirī*) to determine the altitude of the sun. His special design of a two-part meridian ring, the inner part moveable and the outer stationary, combines the advantages of both forms of rings. Such a form of meridian ring is not known to occur among extant globes, although there may once have been a similar gnomon ring on globe No. 5.

The thirteenth-century astronomer Abū ᶜAlī al-Ḥasan ibn ᶜAlī ᶜUmar al-Marrākushī (died AD 1261) includes an interesting section on the design and construction of the rings for a celestial globe in his treatise on astronomical instruments.[77] He begins by explaining a technique for determining the diameter of a given globe by means of a geometrical construction on a plane surface using only dividers and drawing compasses. Once the diameter is determined, he says to make two metal rings each of inner diameter equal to that of the globe. One of the two rings (the one to be the horizon ring) should be twice the width of the other. One face of the horizon ring should be divided into four equal parts and each of these into 90°, which are then labeled in such a way that there are two zero points diametrically opposite labeled East and West, and with the numbers converging at two opposite points of the ring that are labeled North and South. Indentations are than made at the north-south points, equal in width and breadth to the meridian ring.

A semicircle of metal is then attached firmly at right angles to the underside of the horizon ring at the east-west points. In the middle of this arc a notch is made to hold the meridian ring and prevent it from wobbling. Three columns of metal slightly higher than the radius of the globe are fixed firmly to the underside of the horizon ring at equal distances from one another. One face of the meridian ring (that which will face east when placed in the horizon ring) is then divided into four parts, each graduated into 90° by lines extending to the outer edge of the ring. Holes are then drilled through the ring at every degree around half of the ring (probably a 180° segment between the two points where it will be attached to the poles of the globe). Then the maker is instructed to produce a *māsikah* (tongue) of metal, which is attached by a pin to the upper face of the horizon ring near the south point so that it turns around the nail in order that the pointed end can be inserted in any one of the holes of the meridian ring. In this way the meridian ring can be held stationary and secure at any desired terrestrial latitude. Then al-Marrākushī directs the maker to file down and bevel the face of the meridian ring that is not graduated so that it slants in toward the inner edge; by this wedge shape al-Marrākushī feels that as much as possible of the surface of the globe will be exposed to view.

Two grooves are to be cut into the meridian ring, but not going through it, beginning at the inside edge of the ring. They should be placed precisely opposite each other and positioned on the meridian ring so that the middle of each marks one end of the 180° segment of the meridian ring where holes had earlier been drilled for each degree. Into each of these grooves there is to be inserted a metal *unbūbah*, which is presumably a hollow pin or cap attached to each of the celestial poles of the globe.

None of the extant Islamicate globes reflects al-Marrākushī's particular design of the meridian ring with its beveled shape and holes placed at every degree for 180° through which a "tongue" could be slipped to set it for a particular geographical latitude, and its grooves in which the axis of the globe are set. His description reflects a theoretical rather than a practical interest in

globe making, as witnessed by his mathematical determination of the diameter of the globe. He never mentions the tools and processes necessary for constructing such rings and appears to have had little practical experience himself, since it would be virtually impossible to drill a hole through the meridian ring at every degree unless he were making a globe and ring of monumental size.[78]

Although the extant rings do not correspond in detail to what could be produced by the methods described above, it is obvious that procedures were used that required considerable skill, special equipment, and techniques for executing the rings to the desired size and for measuring and marking accurate graduations. No doubt most metalworking techniques, even for intricate scientific instruments, were taught in workshops and through an apprentice system, for which reason the artifacts themselves must serve as our major source of information as to their design and construction. From these artifacts sufficient information is obtained to warrant considerable admiration for the makers. This applies particularly to the matter of the spheres themselves, in which case the entire method of casting hollow seamless globes is not mentioned in the literature, but the existence of such a process has been confirmed beyond doubt by laboratory analysis.

Since there is no mention or description of casting hollow seamless spheres in the literature, we can only conjecture as to the methods employed, relying on some laboratory analyses and comparisons with other metal-working techniques. There are no metal-workers today in any part of the world who are known to cast such spheres. While lost wax casting is a very ancient technique that has been used for centuries to produce elaborate and intricate pieces of metalwork, the casting of a complete sphere presents special problems for a metal-worker. These Islamicate celestial globes are the only examples known to exist of hollow cast spheres.

Throughout this study and in the following discussion the author has chosen to employ the vague terms metal or alloy rather than using more specific terms such as brass or bronze. The term brass usually denotes a binary alloy of copper and zinc, generally two parts copper to one part zinc, with sometimes small amounts of other metals present, while bronze denotes a binary alloy of copper and tin with only small proportions of other elements such as zinc or phosphorus and is generally harder and stronger than brass. The actual composition of copper alloys varied enormously from one area to another and one maker to another, and it is unlikely either of the terms adequately covers the composition of most alloys employed in these globes. Furthermore, the one globe that has been analysed was made of what has been termed a quaternary alloy[79] which has a very high proportion of lead, and if our conjectures are correct more than one-third of the extant globes were made with such an alloy. It is fairly certain that none of the extant globes are made of pure, or nearly pure, copper. The vast majority of the metal globes have a golden cast to the alloy, although a few are very dark brown or nearly black,[80] and one (No. 111) appears to be a silvered alloy.

A metal globe in *hemispheres* could be made in one of four ways: (1) In the sheet metal technique[81] the prepared alloy is first heated and hammered down to sheets of desired thickness (for the walls of the globe). Then a piece of the sheet metal would be hammered omnidirectionally over hemispherical anvils to take up the form of the required hemisphere. The two hemispheres would then be soldered together. (2) In the wrought metal technique[82] the prepared alloy ingot would be formed into the final shape of a hemisphere by systematic hammering over an anvil, using a team of three or more men working in a rhythmic sequence. The technique essentially eliminates the sheet metal stage. It is a very uncommon method today, but was commonly employed until the end of the nineteenth century. (3) In box-mould casting each hemisphere would be cast separately in a fairly simple box mould and then soldered together. (4) In lost wax casting each hemisphere could be produced by using a lost-wax mould, but it is an unlikely method to have been used in this case. It is unnecessarily elaborate for what is the relatively

simple form of a hemisphere.

There is no way to tell from the outside appearance of a globe whether it was made of cast or raised (that is, hammered) hemispheres, if the globe is well done and turned and polished properly. The walls, however, tend to be thicker and the globe heavier when made from cast hemispheres than from raised ones. The determination of the exact method requires examination of the inside for stress marks and confirmation by radiographic analysis.

When we turn to *seamless* globes, visual inspection is even less reliable as the means of determining the construction. A seam is not always visible on a very fine piece of metalwork, even under inspection with a strong lens. For example, globe No. 81 illustrated in Figure 22 does have a seam, but it is not observable outside even when examined in great detail. When the globe is turned over and over, you can detect a very slight difference in sphericity when compared with the more uniform sphericity of a seamless cast one such as the Smithsonian Institution globe, No. 38. Most importantly, no circular or square plugs can be detected, such as are visible on the globes in Figures 11, 12, 26, and 35. The lack of such plugs should suggest that the globe may well in fact have a seam, although there are some globes that were coated by the maker with different substances which cover most of the traces of such plugs. If no plugs are to be seen, one method, of ascertaining whether it has a seam is to insert a thick wire or probe through one of the axis holes to see if the ridge from a seam can be felt inside the globe, as is the case with No. 81 (Figure 22). In the case of a seamless globe there are often protruberances or rather short stumps inside the globe; thus one must be careful to distinguish these from a continuous ridge indicating a seam. In some cases it is not possible to decide definitely even with a pliable probe, and most globes do not admit much visual inspection without special equipment. Occasionally a globe will be missing a large plug (see Figure 36) and a person will be able to see readily that there is no seam. The plugs are not repairs, but are part of the construction process. Since plugs are frequently not visible to the naked eye or even with the aid of a lens, one must be very careful when asserting that a globe has a seam or not.

In Table 6 (Chapter 7) the 50 globes that have been listed as hollow metal seamless globes all have visible plugs from the casting process. The 41 classified as metal globes made in hemispheres all have either a clearly visible seam on the outside or one that can be detected by a probe on the inside, leaving 26 metal globes that could not at this point be classified. The most certain method of confirming the construction is the use of radiographic analysis.

Assuming that you can demonstrate that there is no seam in a hollow metal globe, there remain two possible methods of construction. The first is called raising.[83] This involves taking a sheet of alloy and hammering it omnidirectionally over various spherical anvils until a nearly complete sphere was attained. The large plug that is frequently visible on seamless globes (see Figure 12) and which would have filled the hole evident in Figure 36, could be interpreted as a plug placed over the final opening; the smaller plugs such as those in Figure 35 could be seen as filling other holes made in the sphere for the insertion of raising tools, necessary so that the outer surface could be beaten with a hammer. An argument in favor of such a method being used is the thin metal cross-section of the globes, which appears to modern metal-workers upon first consideration to be much too thin for casting.[84] The interior surfaces of all the globes so far inspected have revealed the rough and pitted texture characteristic of casting rather than the stress patterns visible in a raised object. I know of no hollow metal seamless globes that have in fact been raised, but admittedly only a small number have actually been inspected.[85]

The second possible method would be casting by the lost wax method.[86] This method would also require that the finished product have several plugs, one of considerable size, and would produce relatively thin walls. Such a method would result in the interior surface being rough and pitted with stumps projecting inside, and

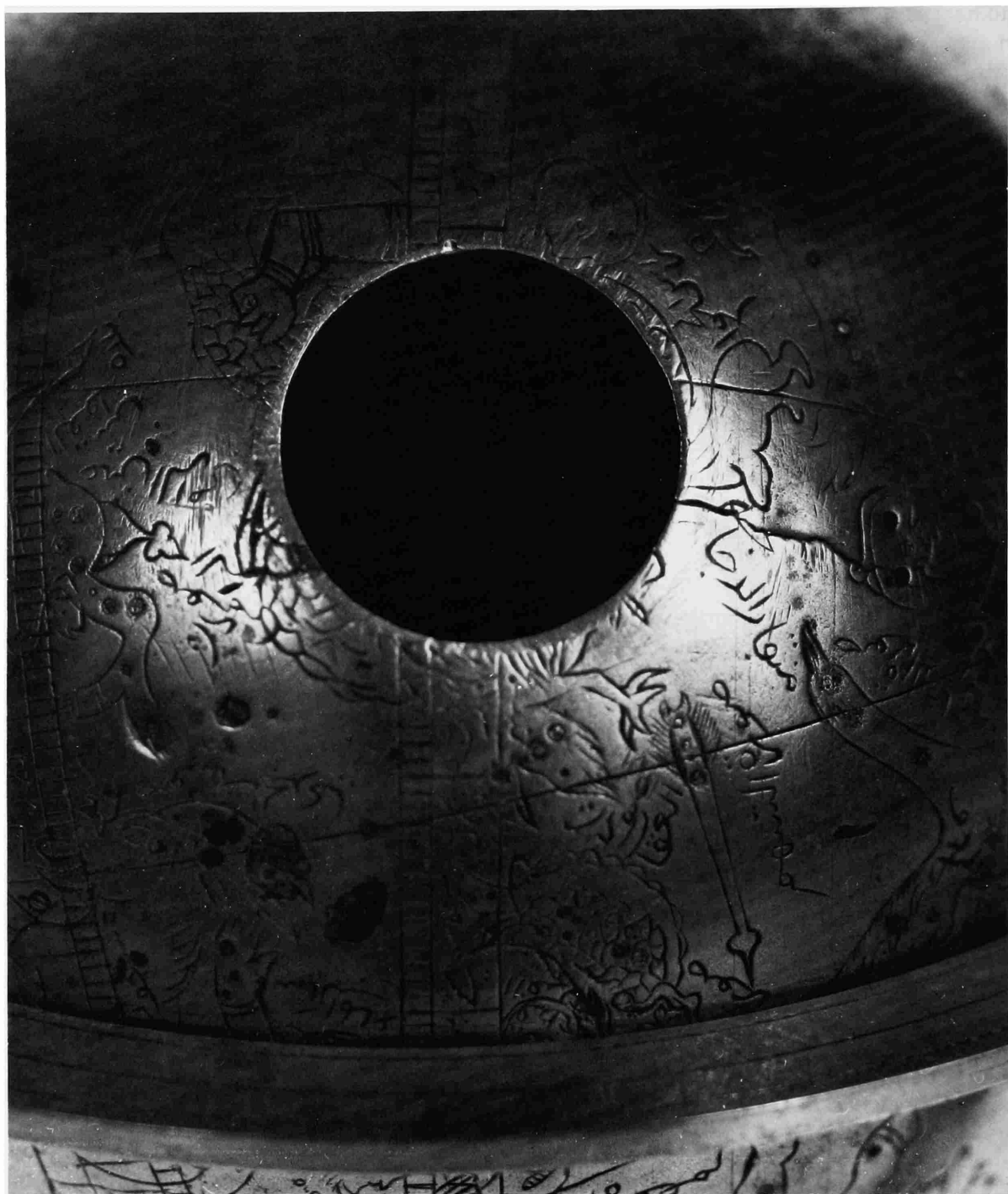



FIGURE 36.—Detail showing the area where the plug has been removed. Globe No. 12, dated 1035 H/AD 1625–1626, by Qaʾim Muḥammad of the Lahore workshop. Paris, private collection. (Photo: Alain Brieux)

would probably result in noticeably better sphericity than would be obtainable by raising. Close inspection of the inside surface can be important in determining whether a seamless sphere has been raised or cast.

The Conservation and Analytic Laboratory of the National Museum of American History at the Smithsonian Institution, undertook an analysis of an unsigned and undated seamless metal globe that can definitely be attributed to Qā᾿im Muḥammad of the seventeenth-century Lahore workshop (see Chapters 3 and 4). This globe would have been the most precise of all the globes made by that prolific workshop had not the maker at the last moment made a mistake when engraving one of the tropics and ceased work on the object, since it is impossible to correct an error on metalwork. The laboratory employed radiography, metal analyses, and hundreds of photographs of the inside taken with a tiny camera.[87]

The alloy was found to have copper as the major component, but it also contained over 30% lead, plus zinc, tin, and traces of other metals. The high lead content is in keeping with recent analyses of Persian items (which did not include any globes) of the twelfth through the sixteenth centuries.[88] These analyses found that a substantial group of cast items (buckets, bowls, mortars, etc.) were made of an alloy containing from 12% to over 40% lead. The precise measurement of the lead is difficult on lead-rich objects because of the segregation of lead during the cooling of the object. This is a quaternary alloy, for its components are, in descending order, copper, lead, zinc, and tin (Cu > Pb > Zn > Sn), with a trace of other elements, and with the lead always over 12%.

The reasons for employing such a lead-rich alloy in casting would be the resulting lower casting temperature and the greater fluidity of the alloy, which would be quite important in filling a spherical mould. Moreover, greater malleability is obtained, which is particularly useful if decoration is to be engraved on the object.[89]

The laboratory found the walls of the sphere to be unexpectedly thin (0.47–1.0 mm) in relation to the diameter (217 mm) of the sphere and in relation to the weight (2976.7 gr). Again, the lead-rich alloy would account for the unexpected weight.[90]

On the basis of a recently published anthropological survey of metalworking techniques and workshops in India[91] combined with the results of the laboratory analysis conducted at the Smithsonian, we can conjecture a fairly detailed picture of the procedure that might have been followed in manufacturing such a globe by lost-wax casting.

The first step would be to form a center spherical mould, which might be either solid or hollow. A solid center mould would have been quite heavy, but would hold more firmly on the lathe. If hollow, it could have been built up by using ropes or coils of clay and building and shaping it into a sphere much as is done in making clay bowls. If solid it might be formed from earth with cow or goat dung (presoaking the dung in water and grinding it in a mortar and pestle and then grinding it with equal amounts of clay); or with equal amounts of sticky clay, sandy clay, and old cloth; or with river clay and bran.[92] The spherical mould thus formed would be allowed to dry, and a hole would be bored in it by which it could be placed on the turning-lathe and turned until quite smooth and spherical.

A wax wrap would then be applied to the center mould. Beeswax is formed into wires by forcing it through a sieve so that each filament has the same thickness. The wires of wax are then neatly wrapped around the core and smoothed with a knife. The center mould with wax wrap is then turned on the lathe, producing a wax covering about 0.5–2.0 mm thick, with an opening where it had been inserted on the lathe. No design is put into the wax, for in the case of celestial globes all decoration is engraved later onto the finished cast product.

An outside investment of clay is then necessary to complete the mould, but before that can be done several preliminary steps must be completed. Channels must be added to the wax wrap to serve as runners (also called feeders). To do this, wax wires could be attached to the wax wrap

(and then coated with the outside clay mould except for their upper ends). These melt when heated and leave hollow channels connecting with the then open wax space where the wax wrap had been.[93] Bamboo sticks could also be placed just touching the wax wrap. These would be coated with the outside clay and when the clay was dry, removed to leave a hollow tube. The placement of these channels is very important, particularly in the production of a sphere.

Armatures (also called chaplets) must also be inserted. When the wax runs out of the mould the two surfaces of the mould would fall together unless prevented by some supports. To prevent this the maker must, before the outer clay coat is applied, insert pins or nails, driving them through the wax and into the center core. These will be imbedded in the outer clay mould. If the worker is skilled, the nails will be of the same alloy as the main casting. The armatures must be positioned evenly over the surface, up to twenty or so in number, depending on the size of the casting.

Then the wax wrap, and runners and armatures, must be covered with clay. This must be done soon after the wax wrap is formed or it will harden and crack. The outside clay investment most frequently employed today in India is made of sandy river soil moistened and ground to a fine paste. If an especially smooth surface is required (which would probably be the case with a globe) the earth is mixed with cow dung. The paste is applied over the wax wrap until it is about 10 mm thick. When this has dried, the mould is then recoated with common earth and bran (or clay, goat dung, and sand, or a mixture of ant-hill dirt and rice husk) until the coat is about 25 mm thick. At this point the bore in the center core by which it had been turned on the lathe would need to be filled.

The completed mould is then inverted and baked. The wax runs out through the runners and the main opening in the outside encasement. The wax is usually recovered to be reused later.

The actual casting of the object was probably done by a different craftsman from the one who made the mould, as is seen in contemporary workshops in India. The main pouring point (called a sprue) was probably the opening in the wax wrap where it was inserted onto the lathe. Possibly some of the runners were used as additional pouring points. Other runners would be allowed to fill up as the mould was poured. The alloy would continue to be poured until it rose in the runners. The alloy contracts when cooling to such an extent that runners containing extra alloy are needed to fill the spaces. If there are an insufficient number of runners, a pock-marked area of porosity will result in the finished product, which must then be filled with plugs. This appears to be a major problem in casting a sphere, judging from Smithsonian globe, which has such an area.

When the metal is cool, the outside mould is broken off and the runners and armatures cut away. To remove the inside mould, a circular plug had to be cut out (usually 40 to 60 mm in diameter and probably at the sprue). Through this opening the inside was dug out, a most laborious and tedious process. And through this opening all work on the inside took place.

The armatures in most such castings are merely broken off and then polished down on the outside, leaving a stump protruding on the inside of the mould. This appears to have been done with many of the armatures on the Smithsonian globe, but some also seem to have been removed and plugs inserted, made of the same batch of alloy as the body of the globe. In the Smithsonian globe nearly all the plugs (except the two largest ones one of which was the last to be put into place) were actually hammered into place from the inside and then smoothed and polished on the outside, using no solder. The laboratory analysis of the Smithsonian globe disclosed 74 plugs in the globe. The large round plug where the sprue was and the last to be placed in the globe is indicated by arrows in Figure 77. It is rather difficult to detect on the globe unless you already know where to look. Most of the smaller plugs are equally difficult to see, if not more so. On many globes this large round plug is quite obvious (see Figure 12). Occasionally the final plug has the shape of a figure-eight, as seen

in Figure 18. This final plug would have beveled edges and be held in place with soft solder. There are globes in which the large plug has been removed and the beveled edges of the surrounding area of the globe can be seen (see Figure 36, where the plug was pryed out of the globe). Some sprue plugs are elongated ovals. There are some globes (e..g., Nos. 23, 44, 85, and 87) that have two large round plugs placed precisely opposite each other on opposite sides of the sphere; why they are so positioned is unknown. Some of the globes are biased in weight (e.g., No. 23) probably because of a thick and heavy plug causing the uneven distribution of weight. The globe illustrated in Figure 25 has the final plug made of an entirely different alloy from the rest of the globe.

Figures 51 and 54 show a weak area that probably occurred because of poorly placed runners. In this area there are 17 large plugs, 7 small square ones, and 6 round ones, some of which are indicated by arrows. Most of these were hammered from the inside as is evident from the mushroom shape of the interior surface of the plugs. Rectangular or irregularly shaped plugs are generally the result of patching an area where the alloy contracted and was not properly filled with the alloy in the runners. Similar ones are indicated in Figures 6 and 35. The small circular plugs usually indicate the location of armatures. In Figure 11 two can be seen to be of a different alloy, while the two of the same alloy as the globe are nearly invisible. The globe illustrated in Figure 26 has several visible circular plugs, the largest one probably being a patch rather than an armature. This particular globe is missing its large round plug at the sprue hole. One of the circular armatures is visible in Figure 58 (marked by the arrow) and a large one can be seen in Figures 61 and 62.

After the casting and plugging process was completed the sphere would be turned on a lathe and polished; after the engraving and placement of the stars it was polished again (evidence of polishing is visible in Figure 35). Scrubbing the product with different compounds could produce various finishes. For example, a scrubbing with tamarind water and sand produces a matte finish. Perhaps some such compound was used to produce the very dark, nearly black matte finish on globe No. 28 (Figures 40, 43, and 47). Occasionally globes (Nos. 100 and 115) have a black or brown surface coloring that is not "fast" (it rubs off when energetically scoured). It obscures seam lines, plugs, and other evidence of construction. One method of obtaining such a surface coloring is to heat the item and smear it with a mixture of charred coconut fibre and mustard oil. As the metal cools, the color sets.[94]

In the workshops there was probably much division and specialization of labor, just as can be seen in workshops today,[95] where several artisans are involved in producing the basic item and other craftsmen work on designing and engraving the finished product. The precision and the uniformity in the sphericity of a seamless globe cast by *cire perdue* is impressive. The workshops in the Punjāb and western Himālayas seem to have specialized in this extraordinary technique of producing celestial globes from the sixteenth through the nineteenth centuries. Only pride of craftsmanship could have justified the enormous expenditure of time and effort that went into such a technique, when much simpler methods using hemispheres had long been available. The products of these Indian workshops display admirable skill on the part of the artisans in forming a nearly perfect sphere and inscribing it accurately and precisely. One of the finest examples of their products is the Smithsonian globe (No. 38), which is the particular subject of Chapters 3, 4, and 5.

The Smithsonian Globe

3. Description and Attribution

The Pleiades will mount up in security from the
aggression of Capella and Aldebaran,
And the Milky Way will show forth as a she-camel
cleaving to her young, the twin stars of
Ursa Minor drawing near to her Taurus.
The Lord of the heavens and earth will reveal Himself
to us in His justice and compassion,
And the colonialists will acknowledge defeat, and
the lands will shine forth in prosperity.

Maᶜrūf al-Ruṣāfī
Dīwān

The anonymous and undated Islamicate celestial globe now in the collection of the Smithsonian Institution, National Museum of American History (Division of Physical Sciences, Inventory No. 330,781) was acquired in 1974 from the collection of Ernst Nagel of San Francisco. (The globe was on loan to the Museum from 1972.) This metal seamless globe has a diameter of 217 mm. The thickness of the wall varies from 0.47 mm to 1.00 mm. The globe weighs 2976.7 grams. It is the sixth largest extant Islamicate globe, and is one of only two celestial globes preserved today to be graduated by half-degrees. For overall views see Figures 51, 73, 76, 82, 88, and the cover.

The globe has 48 constellation outlines, which were engraved after the stars (represented by silver points) were placed upon it. A small part of the globe in the region of Serpens (see Figure 59), which probably contained three stars, is now missing. Assuming this to be the case, the total number of stars represented by the maker is 1019. This total included one star not in the catalog of Ulugh Bēg or al-Ṣūfī, but described by al-Ṣūfī as the "overlooked star" in the tail of Ursa Major, by which a man could test his vision. Clearly this star was purposefully added to the globe, for it bears the label *al-suhā* (the overlooked one); this star occurs occasionally on other globes as well (see Nos. 4, 5, and 6 of the Catalog).

In four constellations the maker inadvertently placed an extra star (in Pisces, Lupus, Libra with an extra external star, and Taurus with an extra star in the Pleiades), and in four constellations he omitted a star (Scorpio, Aquarius, Canis Major, and Corona Australis). The positions of the stars (their celestial longitude measured along the ecliptic), correspond roughly to what they would have been in the second quarter of the seventeenth century allowing for an appropriate increment in the longitudes. They are identical to the star positions found on the signed globes produced during the seventeenth century by the Lahore workshop.

The constellations as well as many of the stars are labeled in Arabic, written in *naskhī* script in a manner suggesting an Eastern hand, though it is not the *nastaᵓlīq* used in Persia. The maker misspells 21 out of 48 times the word for constellation (*ṣūrah*), writing it with a terminal form of *tāᵓ* rather than a *tāᵓ marbūṭah.* (A similar mixture of spelling occurs on globes Nos. 11, 13, 18, 20, 22, 23, 27, 28, and 30.) Some elementary grammatical errors and irregular genitive constructions are evident in the Arabic, such as *ṣūrat ᶜuqāb* for the more acceptable *ṣūrat al-ᶜuqāb* (the constellation of the eagle), and *ṣūrat ḥūt janūbī* instead of *ṣūrat al-ḥūt al-janūbī* (the constellation of the southern fish). These elementary errors indicate that Arabic was probably not the native tongue of the maker, while the script itself indi-

cates the globe came from the Eastern part of the Islamic world.

The style of dress worn by the human constellation figures is clearly Mughal—that is, from western India of the sixteenth and seventeenth centuries. This style is shared by globes Nos. 11–15, 18–24, 26–28, and 30, all of which were produced by the Lahore workshop in the seventeenth century.

Having made a general attribution on the basis of the star positions and the general style of the constellation figures, it is possible to go further and make a specific attribution to a particular maker. This can be done on the basis of two approaches, each of which independently provides sufficient evidence to conclusively establish the identity of the maker. The first argument is based upon technical terminology and astronomical features of the Smithsonial globe, and follows immediately. The second is based on the iconography, and is presented in Chapter 4 by Andrea P.A. Belloli.

In Ursa Major the two stars on the lower front paw are labeled *tatimmat qafzah al-thālithah* (the complement of the third leap), while in Pegasus the star in the northernmost hoof bears an undeciphered label, *mrhlt al-faras.* Furthermore, in the constellation Perseus the star name written in the sword held overhead is written as *muᶜtaṣam al-thurayyā* (the refuge of the Pleiades), which must be a misspelling of *miᶜṣam al-thurayyā* (the wrist of the Pleiades). These terms are not known to occur in any star catalog nor on any globes or astrolabes except the globes No. 11 and No. 13, made by Qāʾim Muḥammad ibn ᶜĪsà ibn Allāhdād Asṭurlābī Lāhūrī Humāyūnī made in 1032 H/AD 1622–1623 and AD 1626–1627 (the twenty-second year of the reign of Jahāngīr) and illustrated in Figures 13, 37, 38, and 42. On both of these globes the identical terms are very clearly inscribed. The two other globes by Qāʾim Muḥammad (Nos. 12 and 14) were not available for detailed study, and it is not known if these terms occur on them as well. These very unusual terms appear to be unique characteristics of the globes bearing the name of Qāʾim Muḥammad and do not occur on any other globes, even those made by or supervised by his son Ḍiyāʾ al-Dīn Muḥammad or his nephew Ḥāmid. Unfortunately the globe by Qāʾim Muḥammad's brother Muḥammad Muqīm (No. 15) was also unavailable for close study, but from the available photograph appears to be of a different style from Qāʾim Muḥammad's products.

The positioning of the sequence of lunar mansions along the ecliptic as done on the Smithsonian globe is known to occur on only one other globe, that being the earliest globe made by Qāʾim Muḥammad (No. 11). On these two globes, the first lunar mansion is placed at 13° House of Aries with the twenty-eighth lunar mansion at the vernal equinox, in contrast to the usual arrangement, in which the first mansion is at the vernal equinox and the second about 13° House of Aries (see Chapter 5).[1]

Moreover, the maker of the Smithsonian globe has numbered the ecliptic continuously from the vernal equinox. On all other globes but one the graduations of the ecliptic are numbered in 30° intervals. This one exception is again the earliest globe by Qāʾim Muḥammad (No. 11) where he labels the ecliptic continuously from the vernal equinox as well as giving it a second set of numbers which divide it into 30° intervals. Finally, the star positions on the Smithsonian globe are identical to those on the globes by Qāʾim Muḥammad that have been examined.

In the subsequent chapter Andrea P.A. Belloli also attributes the globe to Qāʾim Muḥammad, based on the iconography of the workshop. For these reasons this anonymous and undated globe can with confidence be attributed to Qāʾim Muḥammad ibn ᶜĪsà ibn Allāhdād Asṭurlābī Lāhūrī Humāyūnī.

The construction of the Smithsonian globe appears to be like the other examples of the Lahore workshop—hollow, metal, and seamless, with several plugs visible. The Analytic and Conservation Laboratory of the National Museum of American History of the Smithsonian Institution undertook an extensive analysis of this globe, involving radiography, metallography, and metal analysis. It is to be hoped that this detailed analysis will be published. For the moment it must suffice to give some of the general conclusions.

The radiography proved convincingly that the globe was not raised from a metal disc, but rather was cast as a hollow, seamless globe by the *cire perdue* method. Seventy-four plugs were found in the globe, only a few of which are easily visible. All are made of the same alloy as the rest of the globe. The alloy was found to have copper as the primary component, with over 30% lead, plus zinc, tin, and traces of other metals. A large round plug, rather difficult to see, is found at the end of Eridanus (see Figure 77). This plug is at the place where the sprue was located—that is, where the alloy was poured into the mold. A weak area occurred around Draco, Cepheus, Hercules, and Serpens, where there is a small part missing (see Figure 59), and there are in this region 17 large plugs, 7 small square ones, and 6 round ones, the latter being the location of armatures or chaplets which protrude on the inside. Some of the plugs are indicated by arrows in Figures 50, 52, and 54. Many of the plugs were hammered into place from the inside. This is evident from the mushroom shape of the interior surface of the plugs. Soft solder was employed in securing the large plugs.

The globe was turned on a lathe for smoothing and polishing. The precision and the uniformity in the sphericity of the globe is impressive. This is generally true of seamless cast globes.

The alloy employed was highly leaded, probably to increase the fluidity. The circles, graduations, figures, and writing are engraved, not etched, and it is evident that the engraving of the figures was done after the placement of the stars, for some of the outlines are incised over the stars. The silver studs used to represent the stars were soldered in; they do not go all the way through the wall of the globe.

Although analytic tests have been conducted on only this one globe, which we feel certain was produced by Qāʾim Muḥammad of the seventeenth-century Lahore workshop, it is likely that the other globes by the workshop were made by the same *cire perdue* process, as were probably other products of northwestern India. The three apparently seamless globes that appear to be of an earlier date and from outside of India (Nos. 6, 9 and 60 illustrated in Figures 6, 7, and 8) were also likely to have been made by the lost-wax method and of a similar heavily leaded alloy.

Twenty-one celestial globes were produced by this workshop and inscribed with the name of the master craftsman and the date of completion. The question naturally arises as to why this globe was not similarly inscribed. It is quite probable that the maker, after completing the tedious construction of the sphere and the precise placement of the stars, the drawing and graduation of the great circles, delineation of the constellation figures and labeling of the stars, began to draw the equatorial tropic circles. In the northern hemisphere of this globe a lesser circle parallel to the equator but not in the position of the Tropic of Cancer was partially drawn (see Figures 73 and 76). It would seem that having started to draw the tropics, the maker discovered that he had placed the northern circle too far from the equator. For this reason the maker may have stopped incising the circle and ceased work altogether on the globe, for such an error in engraving would be impossible to correct. This may well be the reason the globe bears no maker's signature and date, which were no doubt the last items to be added to a globe.

4. The Constellation Figures on the Smithsonian Globe

Andrea P.A. Belloli

Over the black dome of the sky
the veil hangs deep,
Whereon the stars soft-cradled lie,
Like flowers asleep.

Ilyās Abū Shabakah
Night-presence

The purpose of this chapter[1] is to examine the Smithsonian celestial globe (No. 38 in the catalog) not as a technical device, but as an art historical document. The interest of such an object for the art historian lies most specifically, of course, in the constellation figures on its surface. Ideally, an analysis of these figures in stylistic and iconographic terms can complement technical study by providing a way to suggest or verify attributions of anonymous, undated objects to particular metal-workers. Thus, the argument that follows is presented in terms particular to the discipline of art history, with a methodological caveat. An attempt will be made to put aside the aesthetically based terminology used by scholars such as Wellesz in favor of a factual examination of what were, first and foremost, pure and simple diagrams. Our aim, then, is to formulate a firm attribution and date for the Smithsonian globe itself on the basis of stylistic criteria objectively described and evaluated, just as one would evaluate information gathered from a written rather than a visual document. Factors to be considered include the particular manner in which the basic constellation diagrams, known from earlier globes and the al-Ṣūfī manuscript tradition, were rendered in this instance; the iconographic peculiarities of the figures and their relation to counterparts on earlier and contemporary globes; and the significance of contemporary factors relevant to the globe's manufacture.

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Each constellation figure on the Smithsonian globe is presented in simple outline form. The use of such an outline to delineate each figure is a feature common both to the illustrations to the manuscripts of al-Ṣūfī's *Kitāb ṣuwar al-kawākib (Book of the Constellations of the Stars)* and to most Islamic globes. The garments of the human figures on the Smithsonian globe have none of the tiny, nervous folds and bunched undulations seen in early al-Ṣūfī illustrations such as those in Oxford Bodleian MS Marsh 144 (dated 400 H/AD 1009–1010).[2] Rather, the drawing of the figures on the Smithsonian globe is clear and straightforward; groupings of parallel straight or curved lines or hatchings to indicate surface texture or pattern are kept to a bare minimum. Such decorated areas include Virgo's wings, a cross-hatched detail on Cassiopeia's throne, and the striped or pleated kilt-like skirts worn by Hercules and Serpentarius, as well as the scaley bodies of Pisces, Draco, and Serpens. Many of the human figures, including Auriga, Hercules, Serpentarius, Virgo, Orion, and Aquarius, have been rendered with two left or two right feet, while on some figures the hands have too many or too few fingers (e.g., Virgo, Hercules, Cassiopeia, and Aquarius). Both Perseus's and Hercules's left arms, which are raised over their

heads, end in right hands.

Almost all of the human figures have roughly heart-shaped faces with broad, smooth foreheads; some have slightly pointed chins, while others possess squared-off jaws. The one exception is Virgo, whose head is longer and more truly rectangular in appearance, perhaps to accommodate the two large stars that fall here on her cheeks; although these are not labeled on the globe, al-Ṣūfī refers to them as no. 3 *al-shimālī min al-ithnīn al-tāliyīn li-humā fī al-wajh* (the northerly of the two consecutive stars on the face) and no. 4 *amyalhumā ilà al-janūb* (the one more inclined toward the south of the two stars).[3] Most of the figures have prominent ears, some (see Aquarius and Serpentarius) with the pointed or curling lobes seen also on the animal figures of Leo and Draco. The eyes of each figure are almond-shaped, in some cases blank and in others containing single, short hatch-lines to indicate pupils. Simple, comma-like eyebrows and noses formed by slightly curving lines ending in knobby points and simple curls characterize all the figures' physiognomies except for those of Orion and Virgo. The latter figures have eyebrows that join with the bridges of their noses to form continuous lines. Mouths are indicated by single straight or semicircular hatch-marks. Male figures such as Hercules wear moustaches consisting of two broader horizontal incisions between nose and mouth, while the beards of Perseus, Cepheus, and Centaurus are formed of short, parallel striations following the chin-line and culminating in a rough point.[4] The hair of all the figures, both male and female, was incised in long, narrow, slightly curving, blade-like forms growing out of the top or back of the head and fanning out slightly at either side; in the case of Hercules and Serpentarius, the leaf-like appearance of these coiffures is enhanced by palmette terminations and small knobs or curls.

The rendition of human hair styles on the Smithsonian globe is markedly different from conventions observed in al-Ṣūfī manuscripts such as Oxford Bodleian MS Marsh 144 and later versions such as those in Leningrad (dated AD 1606) and Copenhagen (dated AD 1601–1602),[5] where we are given a sense of contemporary tastes in both male and female coiffures. The maker of the Smithsonian globe rendered human hair (and also certain details of animal fur) in a manner seen in one of its earliest manifestations on globe No. 5 (probably thirteenth to fourteenth century AD).[6] On the latter, many of the figures' coiffures are represented as long, blade-like bunchings as are the manes of Leo, Pegasus, Ursa Major, and other animal figures. This convention for animal figures may be pre-Islamic, since it can be seen in Oxford Bodleian MS Marsh 144 on figures such as Pegasus,[7] though the hair of the human figures in that manuscript was painted in large opaque areas of black ink.

All of the human figures on the Smithsonian globe wear simple tunics or short skirts, with the exception of the Gemini, whose naked, rubbery bodies are unarticulated save for digits on hands and feet. The representation of the Gemini as naked figures—usually of indeterminate sex—is distinctly more common both on globes and in al-Ṣūfī illustrations than their portrayal as clothed figures.[8] The twins are usually seen from the front in three-quarter view with arms outstretched and overlapping. The human upper torsos of Sagittarius and Centaurus on the Smithsonian globe also appear to be naked, and are unarticulated as well. Hercules and Serpentarius are bare-legged, and wear short striped or pleated kilt-like skirts; the outlines of Hercules's arms end in half-circles on his chest.[9] Both of these male figures appear to be bare-chested, though it may be that double or triple bands at wrists, elbows, and upper arms were intended to be read as drapery folds or decorative bands on fabric, rather than as jewelry worn on bare skin.

The supposition that these bands represent sketchily rendered drapery folds is based on a comparison of the garments of relevant figures on the Smithsonian globe with figures on globes of different dates whose clothing was finished off in every detail. On globe No. 5, for example, figures such as Auriga and Perseus wear ring-like or bunched cuffs and *tiraz* bands,[10] while Andromeda on No. 26 (dated 1071 H/AD 1660–1661) has parallel bands on her cuffs and lower

and upper sleeves.[11] Serpentarius, however, was often represented as a bare-chested figure; examples include the figure on globe No. 5 itself, and that in the Copenhagen al-Ṣūfī manuscript.[12] This type of representation appears to have been the exception rather than the rule. What can be said with certainty is that the maker of the Smithsonian globe did not clearly define the details of dress necessary for any easy reading of each figure as draped or undraped; this stylistic clue will aid us in formulating an attribution of the globe to a specific metal-worker.

A number of the other constellation figures on the Smithsonian globe wear garments with unpleated short skirts; in the case of Aquarius and Andromeda, the neckline (or a necklace) is indicated by a row of small circles around the shoulders. This sort of beaded or pearl necklet is an occasional component of Andromeda's costume, and can be seen on globes Nos. 5 and 11;[13] other female figures such as Cassiopeia often wear a similar ornament, although the Smithsonian Cassiopeia does not. While Aquarius's garment has a simple band at wrist and hems, Andromeda's is sashed below the belly and has striped borders. Cassiopeia and Perseus wear similar sashes and, in contrast to the aforementioned figures, wear footgear. Perseus wears winged boots decorated with a scale pattern; he also wears two small pockets or purses at his belt.[14]

Four of the male figures (Boötes, Auriga, Orion, and Cepheus) wear long-sleeved, short tunics belted or sashed at the waist; these tunics have simple round necklines or wrap around to be fastened at the side. Virgo wears a similar sashed tunic, but it reaches her ankles. Both Auriga and Cepheus have extra bands or sashes at their belts that curve back over their hips. Boötes wears low winged shoes[15] and two pockets or purses at his waist; Cepheus sports knee boots decorated in a large geometric pattern.[16] Cepheus, Auriga, and Orion each wear particular headgear: Cepheus, a pointed cap topped by three feather-like forms; Auriga, a circle-like turban with fluttering end; and Orion, a low scalloped cap.[17]

The constellations representing real and mythological animals are also outlined in single, roughly continuous lines, with characteristic anatomical details receiving a bit more attenion than in the human diagrams. The contrast between the rendition of the human constellations according to a single, standardized type and the anatomical individualization of the animal diagrams is typical of all the extant globes and many of the al-Ṣūfī manuscript illustrations as well; in fact, it is typical of Islamic art in general. Occasionally within the al-Ṣūfī cycles, small internal variations in facial type can be observed. The shoulders and haunches of the larger and smaller Canis and Ursa figures on the Smithsonian globe are indicated by internal, gently curving lines, and the two dogs have dainty, rounded paws in contrast to the broader paws with pointed toes of such figures as Leo. Ursa's wide, flat tail is distinguished from the pointed tail of Canis Major and tufted tails of Canis Minor and Leo.[18] The various creatures have almond-shaped eyes, some with pupils and some without, crescent eyebrows in some cases (see Ursa Major and Delphinus), and, occasionally, bared teeth (see Ursa Major and Capricorn). Paws are articulated by rows of short parallel striations to signify the surface texture of fur or claw; such lines were also placed around necks (see Cetus), under bellies (see Ursa Major and Canis Major), and across or along foreheads, as in the case of Cetus and Taurus.

The use of such groupings of parallel striations can be seen in Oxford Bodleian MS Marsh 144 and on globe No. 1; in the manuscript, the lines are long, fine, and closely spaced, while on the globe they are short and widely spaced. The convention was also used on globes such as No. 6 (dated 684 H/AD 1285–1286) and No. 11 (dated 1032 H/AD 1622–1623);[19] its presence in two variants on globe No. 1 and in the Marsh manuscript suggest that it would have been characteristic of the earliest copies of al-Ṣūfī's treatise.

On the Smithsonian globe, hatched lines were also used to indicate tails and manes, as were the narrow, pointed, blade-like forms already mentioned as the device for representing human hair. Body-surface textures were indicated in the case

of Pisces, Delphinus, and the reptilian figures of Hydra and Draco; the latter constellation has a particularly individualized face with a long, rolled snout, pointed ears, small curved teeth and beard, and a narrow forked tongue.[20] The bodies of these latter beasts are covered with a scale pattern also used for the wing tops of Pegasus and the figure of Virgo. Pegasus's lower wings are hatched in short thinner and thicker lines as are those of Cygnus, apparently to indicate the overlapping of successive feathers.

It can be seen from this brief analysis of the constellation figures on the Smithsonian globe that the human figures all follow a standard, simple figural type defined by curving, roughly continuous outlines. Harsh angles were avoided although sashes, hair, the corners of hems, and sometimes hands end in single points. Body contours appear rubbery, sometimes bulbous, and there is virtually no internal articulation of body parts except for hands, feet, and basic facial features. Details of dress and decoration received minimal attention. It is clear that the individualization of each figure was less important than the simple outlining of generalized body forms with the addition of a few attributes. The animal figures were rendered in the same fashion, with long, gently curving outlines, a minimum of pointed or angular forms (except in cases where they are anatomically necessary to the animal's recognizability), and a shorthand or cursory indication of skin and fur textures in some instances.

A stylistic comparison between the Smithsonian globe figures and those on the other celestial globes listed in the catalog indicates an extremely close affinity between the Smithsonian figures and those on globes (Nos. 11 and 13) signed by Qā᾿im Muḥammad ibn ᶜĪsà ibn Allāhdād Asturlābī Lāhūrī Humāyūnī and dated to the reign of the Mughal ruler Jahāngīr.[21] The attribution of the Smithsonian globe to this maker, or to someone working closely with him (but *not* his son Ḍiyā᾿ al-Dīn Muḥammad ibn Qā᾿im Muḥammad Mullā ᶜĪsà ibn shaykh Allāhdād Aṣṭurlābī Humāyūnī Lāhūrī), can be confirmed by the examination of individual figures as they appear on the Smithsonian globe, globes Nos. 11 and 13, and the group of globes signed by Ḍiyā᾿ al-Dīn (Nos. 18, 20, 22, 23, 26, 27, 28, and 30).[22]

The figure of Auriga on the Smithsonian globe sits on bulbous, foreshortened buttocks; his left leg appears to be crossed back over his right knee (see Figure 58). The somewhat cramped posture of this figure on this and other globes may derive from his denomination as *mumsik al-aᶜinnah* or "the holder of the reins," a name that suggests the figure might sometimes have been imagined as sitting astride an invisible horse rather than standing in the posture of the classical charioteer. Since Auriga was represented in the al-Ṣūfī manuscripts and on globes either with both knees drawn up or in a standing posture,[23] we appear to be dealing with two separate traditions of representing the constellation, one more closely allied to the original Greek conception of its appearance. This variation in pose may also have arisen out of the necessity of incorporating two large stars, placed here on Auriga's ankles, within the constellation. Al-ṣūfī calls the star on the western upper ankle, no. 10, *alladhī ᶜalà al-kaᶜb al-aysar* (the one on the left ankle-bone), while the star on the eastern lower foot is called no. 11, *alladhī ᶜalà al-kaᶜb al-ayman wa huwa al-mushtarak lahu wa li-l-qarn al-shimālī min al-thawr* (the one on the right ankle-bone and it is common to both this position and the northern horn of Taurus).[24] They were variously positioned on globes and in the al-Ṣūfī copies on Auriga's ankles, feet, or legs.

The eastern shoulder of the Smithsonian Auriga figure slopes in a long curve around a large inlaid silver star, labeled *mankib dhī al-ᶜinān* (upper arm having the rein), to a rounded elbow held close to his waist. He carries a long upright staff with five crescents along it and a trefoil point from which dangles two tasselled ribbons. This resembles a horse whip and is standard on all extant globes, though it appears in a number of different forms.[25] Horse whips are also held by Auriga figures in the al-Ṣūfī manuscripts, though these tend to have thin thongs instead of broad bands.[26] Auriga's western shoulder forms an approximately straight line from neck to el-

bow, and he rests his western fist at his belt. It is this fist that on other globes and in the al-Ṣūfī manuscripts is shown gripping a narrow folded band, no doubt the reins from which the figure derives his name.[27] Auriga's tunic, of unspecified length, has a simple V-neck that curves slightly, and double bands at upper arm, elbow, and wrist. The figure is bald and wears a fluttering turban with a large circle of fabric standing straight up at his forehead to frame two silver stars; al-Ṣūfī refers to these as no. 1 *amyal al-ithnīn alladhīn ʿalà al-raʾs ilà al-janūb* (the one of the two on the head which is more inclined toward the south) and no. 2 *amyalhumā ilà al-shimālī wa huwa fawq al-raʾs* (the one inclined more toward the north, i.e., above the head).[28]

But for three small variations, this figure reproduces almost exactly the Auriga figures on globe Nos. 11 and 13 by Qāʾim Muḥammad (see Figures 37 and 38). One variation involves the placement of the constellation's right shoulder, which, on the signed globes, more closely mirrors the rounded form of the figures' left shoulders. A second difference can be seen in the rendering of the neck and front band on the tunics of Qāʾim Muḥammad's figures, neither of whom wears a belt. Instead, Qāʾim's Auriga figures grasp their front tunic plackets, which continue in single sinuous lines from rounded necklines down around the figures' seats. Thus the striped band that hangs from Auriga's belt on the Smithsonian globe appears on the other globes as the continuation of the tunic's front closure; in all three cases, Auriga's reins have disappeared entirely, and he grasps his own clothing instead.

The final variation that sets the Smithsonian globe somewhat apart from globes Nos. 11 and 13 involves the facial features apparently common to figures of Qāʾim Muḥammad's signed productions. Most of Qāʾim's constellation figures have almond eyes with enlarged circular pupils; sometimes the eyes are surrounded by double lines with eyebrows continuous above them. Noses are rendered as slightly lopsided trefoils or double-lobed forms resembling arrowheads, and, in the case of the Auriga figures on globes Nos. 11 and 13, the horizontal incisions signifying moustache and mouth respectively are accompanied by shorter lines below to indicate chin-clefts. Thus the faces on Qāʾim Muḥammad's figures differ somewhat in their idiosyncratic rendition from those on the Smithsonian globe, although in all other ways the figures on the three globes are almost identical.

FIGURE 37.—Detail showing Auriga. Globe No. 11, dated in the eighteenth year of the reign of Jahāngīr (AD 1622–1623), by Qāʾim Muḥammad of the Lahore workshop. Lancashire, Stonyhurst College. (Photo: M.B. Smith)

The Auriga figure on one of Ḍiyāʾ al-Dīn's globes (No. 23, dated 1068 H/AD 1657–1658) follows the seated posture utilized on his father's

FIGURE 38.—View showing Auriga, Globe No. 13, dated in the twenty-second year of the reign of Jahāngīr (AD 1626–1627), by Qā'im Muḥammad of the Lahore workshop. London, The Victoria and Albert Museum, Department of Metalwork. (Photo: M.B. Smith)

globes, but shows variations that are characteristic of Ḍiyā' al-Dīn's work (see Figure 39). These include the rendering of the figure's nose in a wedge shape and the particularization of his two attributes. His horse whip has been transformed into a staff consisting of a row of clusters of leaf-like forms with two blade-like terminations at the top, and his soft hat is shaped like an inverted bowl with a sash around the drooping brim and a pointed finial. As we shall see, this particularization and attention to detail, stylistic characteristics already noted as being conspicuously absent on the Smithsonian globe and the two globes signed by Qā'im Muḥammad, are the hallmarks of Ḍiyā' al-Dīn's mode of working with the traditional constellation figures.

The Auriga on another of Ḍiyā' al-Dīn's globes (No. 18, dated 1055 H/AD 1645–1646) departs entirely from the seated posture seen on Qā'im's globes and represents the figure standing or walking. Once again, his headdress and whip have been adjusted; he wears a large, floppy turban with a triangular pin or feather, and carries an oversized whip with toothed and tasseled bands tied to one end. His short skirt is unpatterned, and his right hand, rather than grasping his tunic placket or reins, holds a simple necklace ending in two large cross-hatched tassels below his belt.[29] Thus, though his wedge-shaped nose and other facial features connect the figure to those on globe No. 23, the posture and outfitting have been changed so as to give this Auriga

FIGURE 39.—Detail showing Auriga. Globe No. 23, dated 1068 H/AD 1657–1658, by Ḍiyāʾ al-Dīn Muḥammad of the Lahore workshop. Cardiff, Welsh Industrial and Maritime Museum. (Photo: M.B. Smith)

a very different personality; he has been transformed from a classical charioteer into a male figure holding a sort of ceremonial staff (the original significance of which is all but lost) and dressed in contemporary clothing.[30]

The theory that suggests itself here is that while Qāʾim Muḥammad worked within a rather limited framework, avoiding experimentation and giving scant attention to the decorative potential of the figures with which he covered his globes, his son manipulated the traditional forms used by his father, embroidering and adjusting them here and there during his career, which spanned at least 44 years. Ḍiyāʾ al-Dīn's interest in decorative detailing, his care in finishing off his figures, and his attention to variations in surface textures should be mentioned here as being fundamental characteristics of his style.[31]

As further proof of this theory, the kinship of the Smithsonian globe with Qāʾim Muḥammad's work as opposed to that of Ḍiyāʾ al-Dīn can also be demonstrated if we turn to the figure of Virgo (see Figure 68). The figure of Virgo on the Smithsonian globe is an almost exact replica of the corresponding figure on one of Qāʾim's globes (No. 11; see Figure 13). Qāʾim Muḥammad's Virgo is a dumpier figure with thicker legs, and the lines of her gown and its simple banded edges are once again more sinuous than those of the Smithsonian figure. Qāʾim's Virgo has a characteristic trefoil nose, as well as the "inverted" ears[32] seen on other of his figures. On the other hand, the Virgo on globe No. 28 (dated 1074 H/AD 1663–1664) by Ḍiyāʾ al-Dīn is a more slender creature with a long, thin neck and small, egg-shaped head (see Figure 40). In Ḍiyāʾ al-Dīn's hands, her gown has become a more sumptuous affair, with wide pearl bands at the cuffs and upper sleeves, a long, curving sash patterned with circles and stars, and a delicately scalloped hem. She wears beaded anklets and necklaces, and her breasts are visible through her bodice.[33] Her coiffure consists of a row of thick S-shaped curls across the very top of her head;[34] this feature and the treatment of her wings (scalloped only at the top and extending in long, narrow feathers below) differentiate her from her sisters on Nos. 11 and 13 and the Smithsonian globe.[35] In addition, the south arm and wing of Ḍiyāʾ al-Dīn's Virgo are completely visible beneath the ecliptic down to her hand, while on both the Smithsonian globe and globe No. 11, Virgo's southern arm and wing are partially cut by the ecliptic. A disembodied six-fingered hand, drawn large to accommodate a silver star labeled *simāk aʿzal* (an old Bedouin name for the star Spica, α *Virginis*), marks the end of her southern arm at roughly knee level on the Smithsonian figure; her wing tip is visible just below this hand.

Comparisons of other human and half-human figures could be made with their counterparts on globes by Qāʾim Muḥammad and later globes by his son to flesh out more fully the attribution of the Smithsonian globe to Qāʾim himself or a

FIGURE 40.—View showing Virgo. Globe No. 28, dated 1074 H/AD 1663–1664, by Ḍiyāʾ al-Dīn Muḥammad of the Lahore workshop. Oxford, Museum of the History of Science. (Photo: M.B. Smith)

close associate. From these two examples alone, however, it should be clear that Ḍiyāʾ al-Dīn's interests or points of visual reference differed in certain basic ways from those of his father, and that the Smithsonian globe fits in with Qāʾim's uncomplicated style of around the 1620s rather than with his son's more detailed and experimental way of working. A survey of the animal constellations and those representing inanimate objects supports this hypothesis; here we will consider only the figures of Leo and Argo Navis, two of the more prominent of the non-human constellations.

The figure of Leo on the Smithsonian globe consists of a thick-chested feline with extremely short front paws, each ending in four pointed toes (see Figure 67). The rest of Leo's body has a somewhat telescoped appearance due to his exaggeratedly high rump (placed to encompass a group of stars, the largest of which is labeled *ẓahr al-asad* [the back of the lion]), and long, practically straight hind legs ending in narrow paws with pointed toes. The lion's hind leg joints were placed too low and his lower legs drawn flat like long feet, instead of having him stand only on his paws and setting the upper and lower legs at angles to one another.[36] Leo's thin tail curls in a circle around a single large star labeled *ṣarfah* (change of weather, β *Leonis*), with its tufted tip radiating outwards in a series of points. The star

ṣarfah was usually placed at the tip of Leo's tail, although on Nos. 1 and 26 the tail curls around the star as it does on the Smithsonian globe and other globes by Qā᾿im Muḥammad and Ḍiyā᾿ al-Dīn. Despite the profile rendition of his body, the lion's head is seen full-face with its features (almond eyes and a trefoil nose) drawn as if on a completely flat surface. Representations of Leo on other globes and in the al-Ṣūfī manuscripts inevitably show the lion's body in profile, but his head is often turned in a three-quarter pose so that both eyes and ears are visible. This is how he was represented in Oxford Bodleian MS Marsh 144; in an al-Ṣūfī manuscript in the British Library, London (MS Or. 5323);[37] on globes Nos. 3, 4, 5; on Qā᾿im's globes Nos. 11 and 13; and on at least one globe by Ḍiyā᾿ al-Dīn, No. 28. This pose was also used in illustrations accompanying astronomical and astrological treatises.[38]

The eyes of the Smithsonian Leo contain hatched pupils. Below his nostrils are two pointed horizontal bands for whiskers; below these, two stars occupy the lion's rounded jowls. The short fur of his mane stands up like a row of flames across the top of his head, with four blades of fur falling down along his neck.[39]

Just as with the figures of Virgo and Auriga, the Smithsonian Leo reproduces almost exactly the leonine diagrams on Qā᾿im Muḥammad's globes Nos. 11 and 13, but for the smallest variation: on globe No. 11 Leo has slightly longer mane fur, and on Nos. 11 and 13 he has double-outlined eyes and what appear to be smiling mouths instead of whiskers (see Figures 41 and

FIGURE 41.—Detail showing Leo. Globe No. 11, dated in the eighteenth year of the reign of Jahāngīr (AD 1622–1623), by Qā᾿im Muḥammad of the Lahore workshop. Lancashire, Stonyhurst College. (Photo: M.B. Smith)

42). Otherwise all three lions, with their vestigial front paws and extremely long hind legs, are practically identical.

On one of Ḍiyāʾ al-Dīn's globes, No. 28 (dated 1074 H/AD 1663–1664), we observe a similar Leo, but once again the form has been manipulated and details added (see Figure 43). Although the general posture and angle of the head were reproduced, Ḍiyāʾ al-Dīn modified the lion's front legs by broadening his shoulders and paws, rounding his toes, and adding a furry ridge along the bottom of the elbow as well as a ring of short hatches around the neck. Leo as depicted by Ḍiyāʾ al-Dīn has more prominent, softly furred ears, and his hind paws are also broader, with a furry edge. Thus, the Leo on globe No. 28 is more particularly leonine in all its parts than Qāʾim Muḥammad's figures on globes Nos. 11 and 13, which are recognizable as felines solely on the basis of their schematized facial forms and characteristically tufted tails.

Ḍiyāʾ al-Dīn's further adaptation of the Leo figure can be seen on two other globes, No. 23 (dated 1068 H/AD 1657–1658) and No. 26 (dated 1071 H/AD 1660–1661; see Figures 44 and 45). While leaving the general outline of the lion's body unchanged, Ḍiyāʾ al-Dīn gave him shorter, thicker hind legs and reduced his hind paws to their natural size; this reduction is especially apparent on globe No. 23. In addition, the lion's head is shown in profile like his body, thus avoiding the somewhat awkward twisting necessary to

FIGURE 42.—Detail showing Leo. Globe No. 13, dated in the twenty-second year of the reign of Jahāngīr (AD 1626–1627), by Qāʾim Muḥammad of the Lahore workshop. London, The Victoria and Albert Museum, Department of Metalwork. (Photo: M.B. Smith)

FIGURE 43.—Detail showing Leo. Globe No. 28, dated 1074 H/AD 1663–1664, by Ḍiyāʾal-Dīn Muḥammad of the Lahore workshop. Oxford, Museum of History of Science. (Photo: M.B. Smith)

FIGURE 44.—Detail showing Leo. Globe No. 23, dated 1068 H/AD 1657–1658, by Ḍiyāʾal-Dīn Muḥammad of the Lahore workshop. Cardiff, Welsh Industrial and Maritime Museum. (Photo: M.B. Smith)

show him full-face. The head itself comes even closer to what might be termed a realistic representation of a particular animal, in that it is broad and short with slightly drooping chin, box-like snout, and small erect ears; the lion's neck has also been thickened to indicate the presence of a mane, although the texture of its fur is not shown. This total profile view of the lion constellation was the alternate type used on globes, and more especially in al-Ṣūfī illustrations; examples include the Leo figures on globe No. 1 and in the al-Ṣūfī manuscripts in the Metropolitan Museum of Art, New York, and in Leningrad.[40] The total profile lion existed from at least as early as the eleventh century, as did the three-quarter version we see in Oxford Bodleian MS Marsh 144.

Ḍiyāʾ al-Dīn's version of a Leo figure unlike that used by his father follows the pattern already observed in connection with his rendering of the human constellation figures. If we turn in conclusion to Argo Navis, we see that he also adjusted this figure. The boat on the Smithsonian globe is a flat-bottomed vessel with a high vertical prow surmounted by a leonine figurehead (see Figure 81). It has open railings along either side, a pergola at the stern, and two furled sails attached to a central mast.[41] A thin double chain falls from the mast down to the figurehead, and three unmarked pennants, one each at the lion's head, the mast top, and behind the mast on the

FIGURE 45.—Globe No. 26, dated 1071 H/AD 1660–1661, by Ḍiyāʾ al-Dīn Muḥammad of the Lahore workshop. Berlin, DDR, Staatliche Museum. (Photo: from Bässler-Archiv)

main deck, fly overhead. The candlestick-shaped oars stick diagonally out of the boat below the prow. The vessel's decoration consists of a row of cusped half-cartouches or bracket-like forms along the forward edge of the prow and a similar but larger form at the boat's bottom.[42] The pergola roof is rimmed with a row of small scallops and topped by a trefoil finial, a larger version of which crowns the mast.

The representations of the Argo constellation vary from globe to globe perhaps more than any of the other diagrams; this may have been due

to local and temporal differences in ship design of a kind more radical than, for example, variations in basic fashions of dress. Not all of the boats have sails, pennants, or even masts. Thus it is all the more significant that the Argo Navis diagram on Qā᾿im's globe (No. 11; see Figure 46) is practically the twin of that on the Smithsonian globe. Ḍiyā᾿ al-Dīn's treatment of the constellation on Nos. 23, 26, and 28 is similar in certain details (the leonine figurehead and bracket-like decoration, for example) but vitally different in others (see Figures 45, 47, and 48). These variations include the lack of sails, the modification of the open pergola into a tall, bud-like form, the elaboration of a central structure based on vase-shaped supports and with another, more elaborate pergola atop it, and the modification of the oars into large, bell-like forms on chains. The shape given to the oars by Ḍiyā᾿ al-Dīn is closest to that on an early globe (No. 4) and the earliest al-Ṣūfī manuscript,[43] though intervening Argo diagrams show many variations. Ḍiyā᾿ al-Dīn's substitution of chains for the oar arms is unusual and possibly unique, and suggests that he interpreted the forms rather as anchors than as oars.[44] Ḍiyā᾿ al-Dīn's pennants have a spotted pattern also used on another of his globes (No. 18), where the Argo constellation received a much more complicated and consistent treatment involving the total modification of its character as conceived by Qā᾿im, even to the substitution of a bird facing backward as the figurehead (see Figure 15). This final detail exists in at least two al-Ṣūfī manuscripts, in the Metropolitan Museum of Art, New York, and the Leningrad versions;[45] while the former Argo diagram shows a feline figurehead, that in the latter manuscript has a bird with a curved beak. This peculiarity of Argo's decoration may ultimately make reference to Aratus's claim that the ship sailed backward, in other words, stern first,[46] and it is interesting that the reversed figurehead was only shown on some versions of the constellation diagram.

The consistency with which the non-human constellation diagrams on the Smithsonian globe reproduce those on globes signed by Qā᾿im Muḥammad, while differing in one significant way
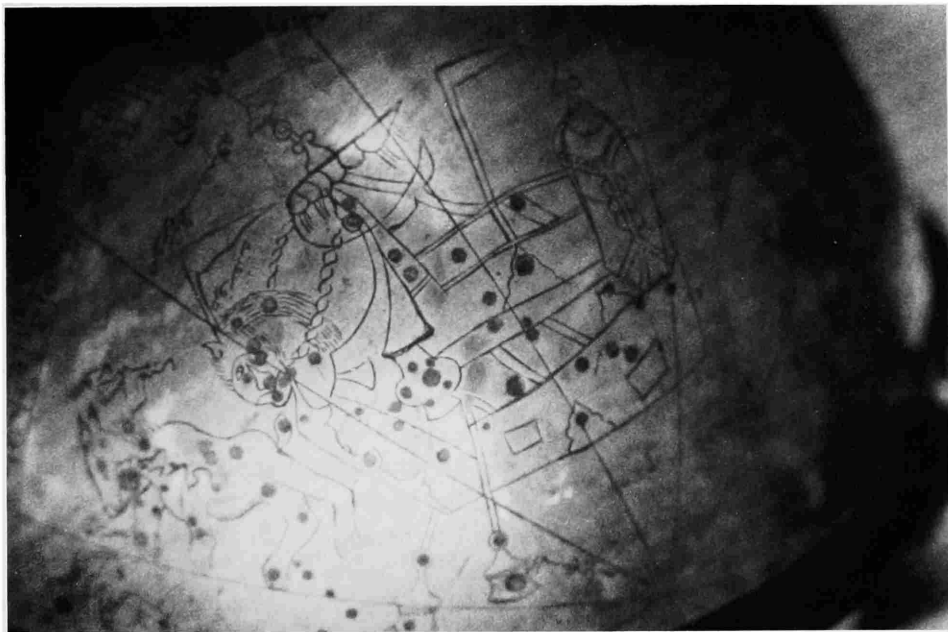
FIGURE 46.—Detail showing Argo. Globe No. 11, dated in the eighteenth year of the reign of Jahāngīr (AD 1622–1623), by Qā᾿im Muḥammad of the Lahore workshop. Lancashire, Stonyhurst College. (Photo: M.B. Smith)

FIGURE 47.—Detail showing Argo. Globe No. 28, dated 1074 H/AD 1663–1664, by Ḍiyāʾ al-Dīn Muḥammad of the Lahore workshop. Oxford, Museum of the History of Science. (Photo: M.B. Smith)

FIGURE 48.—Detail showing Argo. Globe No. 23, dated 1068 H/AD 1657–1658, by Ḍiyāʾ al-Dīn Muḥammad of the Lahore workshop. Cardiff, Welsh Industrial and Maritime Museum. (Photo: M.B. Smith)

or another from those on globes signed by his son, reinforces our original attribution of the unsigned globe to Qāʾim Muḥammad or a close associate. The fact that globe No. 11 by Qāʾim himself is dated AD 1622 (the eighteenth year of the reign of Jahāngīr) suggests a date for the Smithsonian piece somewhere around that year, and, if we can interpret Qāʾim's toponym as an indication of the area in which he worked as well as his birthplace, a locale in northwest India for its production. Certain details of dress point directly to the globe's manufacture in a Mughal context. Such a date and provenance help to explain why many characteristics of Qāʾim's (and Ḍiyāʾ al-Dīn's) figures differ from those on earlier globes and in pre-seventeenth-century manuscripts of al-Ṣūfī's *Book of the Constellations of the Fixed Stars.*

Long- or short-sleeved tunics of varying lengths, sometimes worn over trousers, are standard garb for the human constellation figures on most globes and in the al-Ṣūfī illustrations,[47] and turbans are the normal headgear for the male figures.[48] Usually the tunics are tucked in at the

waist or are belted. Occasionally, figures are represented clad only in skirts; Andromeda on Nos. 4 and 5 was engraved in this fashion. On the Smithsonian globe, with the exception of Virgo, all the figures wear knee-length tunics with long sleeves; in some cases the tunics are pleated. All have a pronounced flare at the waist. They are tied with long, occasionally tasselled sashes below the belly; these sashes are looped up once over the waist. In some cases (see Auriga), a part of the sash also dips back over the wearer's hip.

Such flared tunics, in various lengths, were characteristic male dress at the Mughal court, as can be seen in paintings of the late sixteenth and seventeenth centuries. Work executed during the reigns of ᶜAbd al-Fath Jalāl al-Dīn Akbar (AD 1556–1605) and his successor Nūr al-Dīn Muḥammad Jahāngīr (AD 1605–1627) show courtiers (and also laborers and soldiers) wearing knee- or calf-length tunics[49] tied with a variety of sashes: long, narrow ones worn singly and in pairs tied with a simple knot;[50] short, thicker ones knotted in the same fashion;[51] combinations of both types worn together;[52] or, as on the Smithsonian globe, single, narrow sashes knotted in a short loop that hangs over the waistband. Since few published paintings from this period are definitely dated, it is impossible to say precisely when the single-looped sash came into fashion. A survey of paintings done under Akbar and Jahāngīr shows single-looped sashes occurring in works dated or attributed to the years between AD 1583 and 1610.[53] This suggests that such sashes were popular during Akbar's reign and that the fashion died out completely shortly after Jahāngīr gained the throne.

A preference for the single-looped sash worn by itself on Qāʾim Muḥammad's globes suggests that he must have begun work as a maker of celestial globes during the reign of Akbar, continuing under Jahāngīr without adjusting his mode of dressing the constellation figures to mirror minor changes in contemporary male fashions. Such a theory fits quite well with the generally conservative picture we have constructed of Qāʾim's style, especially in comparison to that of his son. In any event, Qāʾim's particular modification of the outfit standard for male constellation figures on earlier globes to reflect contemporary garb justifies a dating of the Smithsonian globe to the first quarter of the seventeenth century or slightly earlier.

5. A History of Star Names, Based on the Smithsonian Globe

I am the shepherd of the skies,
  Deputed to preserve
The planets as they sink and rise,
  The stars that do not swerve.

Those, as they swing their lamps above
  Our earth, by night possessed,
Are like the kindled fires of love
  Within my darkling breast. . . .

Were Ptolemy alive today,
  And did he know of me,
"Thou art the maestro," he would say,
  "Of all astronomy."

Ibn Hazm
The Ring of the Dove

Classical Greek and Pre-Islamic Sources

The star names used in the classical Islamic world were derived from two distinct sources: the names used by pre-Islamic Bedouins, and those transmitted from the Greek world. As Greek astronomy and astrology were accepted and elaborated, primarily through the Arabic translation of Ptolemy's *Almagest*, the indigenous Bedouin star groupings were overlaid with the Ptolemaic constellations that we recognize today.

From about AD 1500 navigators in the Indian Ocean contributed Persian elements to the star nomenclature.[1] These later influences, as well as the nineteenth-century translation of European star names for the southern constellations not known to classical antiquity, are not reflected in the stars and star names on any Islamicate celestial globes, even those made as late as the nineteenth century.

For the early Bedouin star names and constellation images, the sources of information available today are complex and confusing, although quite rich, and consist mainly of *anwāʾ*-literature and writings of astronomers, such as al-Ṣūfī and al-Bīrūnī, who concerned themselves with comparing the traditional Bedouin terms and conceptions with the later Ptolemaic ones. (See the following section on "Lunar Mansions" for further details on this type of literature and on the pre-Islamic star names and images).

Although ʿAbd al-Raḥmān al-Ṣūfī discussed in his *Book of the Constellations of the Fixed Stars* the early Arab star names and stars, some of which were not described by Ptolemy, the star catalog that accompanies al-Ṣūfī's treatise is strictly Ptolemaic, giving only those stars listed in Ptolemy's earlier catalog with Arabic translations of the Greek names and an occasional earlier Arab name that he could align with a Ptolemaic star. The constellation outlines illustrating the treatise by al-Ṣūfī with very few exceptions depict the Ptolemaic constellations rather than the earlier Bedouin groupings.

References on extant Islamicate celestial globes to the sources used by the makers for the star positions mention three particular star catalogs. Ptolemy's *Almagest* is named on Nos. 2 and 3, the catalog of al-Ṣūfī on Nos. 6, 7, 8, and 62, and the fifteenth-century catalog of Ulugh Bēg on globes Nos. 14, 31, 60, and 64. While it is possible that some of the other Islamic star catalogs were employed by globe makers,[2] it is probable that most makers used one of these three.

In his catalog Ptolemy presented a description of 1025 stars with accompanying ecliptic coor-

dinates for the year AD 138 and designations of magnitude. The stars were not assigned ordinal numbers by Ptolemy, but were described under 48 constellation headings that would usually contain two groups of stars: those formed (μόρφωτοι) and those unformed (ἀμόρφωτοι). These terms refer to whether the stars lie inside or outside the constellation outlines. The number of stars making up each of the 48 constellations was then totaled as so many formed stars and so many unformed ones, and the total number of stars given for the three groupings of constellations: northern, zodiacal, and southern. In the total for the unformed stars of Leo, Ptolemy did not include the three stars of *Coma Berenices* (ὁ πλόκαμος), though he listed them individually in the catalog. Nor did Ptolemy include them in his total for the zodiacal constellations or the total for the entire catalog, which he gave as a total of 1022 stars consisting of 15 of the first magnitude, 45 of the second magnitude, 208 of the third magnitude, 474 of the fourth magnitude, 217 of the fifth magnitude, 49 of the sixth magnitude, plus 9 faint, 5 nebulous, and ὁ πλόκαμος (*Coma Berenices*).[3] Modern writers have confused the issue of how many stars were in Ptolemy's catalog by consecutively numbering every star listed. Since Ptolemy repeated the description of three stars because they each were shared by two constellation outlines (ones shared by Hercules and Boötes, by Taurus and Auriga, and by Aquarius and Piscis Austrinus), though he counted each only once in the summaries of the totals, and because of his failure to include in the totals the three stars in *Coma*, modern writers have concluded there are 1028 stars in the catalog.[4]

Al-Ṣūfī repeated the catalog of Ptolemy, making changes in the longitudes to correspond to 364 H/AD 974, and in some of the magnitudes. He assigned each star a number within the formed or unformed stars of a constellation, including the three stars of *Coma Berenices* in the eight unformed stars of Leo, but did not repeat the description of the three shared stars, so that they were assigned only one number each. Al-Ṣūfī also omitted the last of the Ptolemaic stars in Auriga because it could not be observed. In this way al-Ṣūfī arrived at a total of 1024 stars in his catalog. Of these 1024 stars he noted that the last six (the unformed stars of Piscis Austrinus) were not visible, also adding that no. 11 of Lupus and no. 30 of Centaurus were also not observable. He chose to leave them all in the catalog, however, with a brief statement that they had not been observed. In the text accompanying his star catalog al-Ṣūfī described many stars which he did not give in the catalog, one of them being "the overlooked star" of Ursa Major, which occurs on several celestial globes including the Smithsonian globe (No. 38) and three early globes (Nos. 4, 5, and 6).

When discussing particular star positions al-Ṣūfī frequently refers to celestial globes he has seen. For example, he says that the fifth star of Libra is usually given the northern latitude of 1°40′ when represented on globes following that given in the *Almagest*, but that it ought to be 1°40′ south latitude, and he says that he has seen globes on which the constellation of Libra was depicted as a man holding a small pair of scales.[5]

The star catalog that Ulugh Bēg prepared at Samarqand with coordinates for 841 H/AD 1437–1438 was probably the major reference for the later eastern globes.[6] The catalog essentially repeated the stars and numbering of al-Ṣūfī's catalog of five centuries earlier, with some changes in coordinates, but with the last six stars of the Southern Fish omitted. Thus it had a total of 1018 stars. In the thirteenth chapter of the third section of the preface to this *zīj*, Ulugh Bēg makes the following statements, where he clearly speaks of placing stars on a celestial globe in order to see how the positions in a given catalog compare with those in the sky:

> Before the time of Ptolemy 1,022 fixed stars had been observed. Ptolemy has given them in a catalogue in the *Almagest.* The stars are distributed in six magnitudes; the largest are of the first and the smallest of the sixth magnitude. Each magnitude is divided into thirds, and in order to recognize the stars, 48 figures or constellations have been imagined, of which 21 are north of the ecliptic, 12 in the Zodiac, and 15 south of the ecliptic. The larger number of the stars are within the figures, the others are in the neighbourhood, and are designated as unformed stars of the constellation.
>
> ᶜAbd al-Raḥmān al-Ṣūfī composed a treatise on the stars which all learned men have received with gratitude. Before

determining by our own observations the positions of these stars, we have laid them down on a sphere according to this treatise, and we have found that the greater part of them are situated differently from their appearance in the heavens. This determined us to observe them ourselves with the assistance of Divine Providence, and we have found that they were advanced from the epoch at which al-Ṣūfī's work was written, so that on giving them, according to this general observation, their absolute positions, we no longer found any difference from their appearance to the eye.

It is on this principle that we have reobserved all the stars already determined, with the exception of 27 which are too far to the south to be visible at the latitude of Samarqand, namely the 7 stars in the constellation Ara; 8 in Argo Navis, stars 36 to 41 and 44 and 45; 11 in Centaurus, from the 27th to the end; and one star, the 10th in the constellation Lupus; and we have taken these 27 stars from the work of ᶜAbd al-Raḥmān al-Ṣūfī, taking account of the difference of epoch.

Besides these there are 8 stars mentioned by ᶜAbd al-Raḥmān al-Ṣūfī in his book, of which Ptolemy gives the positions, but which ᶜAbd al-Raḥmān al-Ṣūfī could not find, and which notwithstanding all our researches, we have been unable to discover. For that reason we do not indicate those stars in the present catalogue. These Ptolemy stars are the 14th of Auriga, the 11th of Lupus and the 6 unformed stars of Piscis Austrinus.

In our catalogue we have given the position of the stars for the beginning of the year 841 of the Hegira, so that at any time we may be able to find the place of any stars on the supposition that they advance one degree in seventy solar years.[7]

Despite these statements by Ulugh Bēg, however, al-Ṣūfī *did* omit the fourteenth star of Auriga from his catalog,[8] though he left in no. 11 of Lupus and the six external stars of Piscis Austrinus. Furthermore, all the extant manuscript copies of Ulugh Bēg's star catalog[9] indicate that Ulugh Bēg also left the eleventh star of Lupus in the catalog, despite his statement that he was omitting it.

What appears rather curious then is the frequent use of the number 1022 for the total number of visible fixed stars in the catalog of Ulugh Bēg. For examples, Ghiyāth al-Dīn al-Kāshī in his letter describing the scientific activity of the observatory of Ulugh Bēg says that the astronomers had attempted to construct an astrolabe that had the totality of the 1022 observable fixed stars.[10] Qāʾim Muḥammad ibn ᶜĪsā ibn Allāhdād Asṭurlābī Lāhūrī Humāyūnī on his globe made in AD 1637–1638 (No. 14) states that 1022 stars have been placed on it in accordance with the catalog prepared by Ulugh Bēg. Similarly, the globe by Riḍwān completed in 1701 bears an inscription stating that the number of fixed stars represented on it is 1022 and that their positions were based upon the catalog of Ulugh Bēg (globe No. 31). The globe produced by Lālah Balhūmal Lāhūrī in 1842 (No. 33) also speaks of having 1022 observable stars indicated on it, although Ulugh Bēg's catalog is not specifically named.

The total of 1022 could possibly be obtained by taking the 1018 stars in the catalog, counting the three shared stars twice, and adding in the "overlooked" star of the Greater Bear. The latter star, however, does not occur on the globes that specifically claim to have 1022 stars. It is most probable that globe makers and astronomers simply used the catalog for the coordinates and did not count the precise number of stars. They perhaps continued to use the number 1022 that Ptolemy had given for his catalog and did not note the minor variations from one catalog to another and the consequent changes in the total number of stars.

All globes up through the fourteenth century have the six external stars of Piscis Austrinus. Two of these globes (Nos. 6 and 7) are stated to be based on the *Book of the Constellations* by al-Ṣūfī, and in fact have only 13 stars in Auriga, just as al-Ṣūfī described the constellation in his catalog. The earlier globes (Nos. 1–5 and 34) have 14 stars in Auriga, following Ptolemy's catalog (except for No. 3 which for some reason has 13 stars in Auriga, even though the maker specifies Ptolemy's catalog as the source for the star positions). All globes of the sixteenth century and later were most likely based on Ulugh Bēg's catalog, and on all of them the fourteenth star of Auriga is omitted, as are the six unformed stars of the Southern Fish.

When Ptolemy's *Almagest* was translated in the ninth century, the descriptions and names of the Greek zodiacal constellations were translated into Arabic. In most cases these newer Arabic terms were subsequently replaced by pre-Islamic Arab names. Both the Greek and indigenous

Arabic zodiacal constellations had been derived ultimately from a common Sumerian source.[11] For example, the Arabic translation of the *Almagest* gives *al-rāmī* as the name for Sagittarius, but the older term *al-qaws* (the bow) soon replaced it. Similarly *al-taw'amān* (Gemini), *al-ʿadhrā'* (Virgo), *al-samakatān* (Pisces), and *al-dalī* or *sākib al-mā'* for Aquarius were replaced by the older traditional terms of *al-jawzā'*, *al-sunbula*, *al-ḥūt*, and *al-dalw*. Kunitzsch[12] suggests that the Arabs were more conservative when adapting the Sumerian zodiacal images than were the Greeks, for the Bedouins did not tend to put people with the objects; for example, they imagined a grain of wheat but without the girl (Virgo) or a bow but no centaur (Sagittarius).

In pre-Islamic groupings it seems that *al-dalw* (the bucket) covered the large areas of Aquarius, Pegasus, and part of Pisces; *al-ḥūt* (the fish) covered the regions of Andromeda and Pisces; while *al-asad* (the lion) was much larger than our Leo. This extremely large lion had its nose in what we call Cancer, its eye, forehead, neck, and shoulders in Leo, its one foreleg formed by the heads of Gemini, the other foreleg formed by Canis Minor, its hind quarters in Corvus, and its hind legs formed by Spica in Virgo and Arcturus in Boötes. The liver of this huge lion was the first unformed star of Ursa Major.

Another important image in the Bedouin sky was that of a large woman called *al-thurayyā*. Her head was composed of the open star cluster called the Pleiades in the constellation Taurus. The Pleiades were consequently frequently called *al-thurayyā*. The woman had one arm passing through the regions of Perseus and Cassiopeia where her finger tips were said to be stained with the red day henna, while her other hand was seen in the area now occupied by the Ptolemaic constellation of Cetus. The Hyades, another open star cluster in Taurus, were called young female camels (*qalā'is*) and, according to tradition, were driven before Aldebaran (the follower; *α Tauri*), the most prominent star in the cluster and sometimes called the *fanīq* (camel-stallion), as evidence of his wealth when he went again to court *al-thurayyā*, who had earlier rejected him because of his poverty. Aldebaran's two dogs were seen in two small stars near one another in a narrow space between the Pleiades and Hyades.

The region of the constellations Orion and Gemini was seen in pre-Islamic Arabia to contain a huge giant named *al-jawzā'*, which was possibly a feminine figure originally.[13] The stars in the feet of Gemini, according to some, made up the bow which *al-jawzā'* throws at the huge lion. A throne for him was formed by the stars in the Ptolemaic Lupus and another chair was formed by the stars in Eridanus. Astronomers used the named *al-jawzā'* not only for the Ptolemaic constellation of Orion but also for the zodiacal house and constellation of Gemini. One legend recounts the marriage of *al-jawzā'* (interpreted as a feminine figure) with *suhayl* (Canopus), the second brightest star in the heavens. It was said that *suhayl* lived with *al-jawzā'* but broke her vertebrae and back; so he escaped slaughter by going toward the south, thus avoiding pursuit.

A common Babylonian source gave rise to both the early Arab term for the brightest star in the heavens (*α Canis majoris*) called *shiʿrà* and the Greek term σείριος, from which we get the name Sirius. In the Bedouin tradition there were said to be two Sirii and both were sisters of Canopus (*suhayl* who had married *al-jawzā'*). The southern Sirius was the star in Canis Major which we call Sirius today, while *β Canis majoris* was its companion (*mirzam*). The northern Sirius was the star Procyon (*α Canis minoris*) with its companion (*mirzam*; *β Canis minoris*). The southern Sirius with its companion was called *al-shiʿrà al-ʿabūr* (the Sirius passing over) because it was said to cross over the Milky Way southward toward Canopus when he fled toward the south after injuring *al-jawzā'*, while Procyon with its companion was called *al-shiʿrà al-ghumayṣā'* (the Sirius shedding tears) for it had to remain behind.[14] It was also said that the two stars in Canis Major were called the oath breakers, for when a person who did not know the skies very well would see Sirius and its companion rising he would be willing to take an oath that it was Canopus and its companion star, but he would have perjured

himself when Canopus and its companion really did rise.

There are testimonies from as far back as the third century BC of there being in Arabia animals such as gazelles, lions, wolves, hyenas, hares, onagers, horses, dogs, ostriches, bustards, and perhaps wild dromedaries.[15] Many of these animals, as well as other aspects of pastoral life, can be seen in other constellation images from pre-Islamic Arabia. Gazelles were imagined, and the footprints of their leaps as they ran before the large lion could be seen in the area of Ursa Major. The stars we now view as the body of Cetus were envisioned as ostriches, and the stars of Corona Australis were said to depict an ostrich's nest. Eight more ostriches were imagined in the area now occupied by Sagittarius, four going to the river of the Milky Way and four leaving the river. Camels that had recently foaled were seen in the head of Draco, while some saw a camel formed of some of the stars in Cassopeia while the brightest star of that group was called the camel's hump.[16] In the area of Ursa Minor there were visualized two calves turning a grist mill, and between the two calves and the camels in the head of Draco were wolves. A herd of goats was seen in the area of Auriga, and the stars of Cepheus were viewed as a shepherd with his dog and sheep. The stars Vega and Antares were said to be dogs barking on account of the cold weather. A row of horsemen with an outrider behind were seen in the stars comprising the breast and wings of Cygnus with the outrider made of the tail star. The stars of Corvus formed a tent, and horses and foals were the stars near the stable comprised of Crater. The large star in the tail of Cetus and the star in the mouth of the Southern Fish were called the two frogs, while a leather bucket and rope occupied the areas of Aquarius, Pegasus, and Pisces. Bunches of grapes were seen in the stars of Centaurus and Lupus, and a meadow was imagined enclosed by two rows of stars in Hercules and Serpentarius.

The Milky Way (known in Arabic as *ṭarīq al-tabbānah*, *majarrah* [the course], *umm al-samāʾ* [the mother of the heavens], and other terms)[17] was important in the early imagery, even though it is not indicated on any known Islamicate globe.

The most important modern critical source for the early Arabic star names are the studies by Kunitzsch, which have been used extensively in the following discussion, as well as other secondary sources[18] and some primary ones, in particular the tenth-century writings of al-Ṣūfī and al-Bīrūnī and thirteenth-century tract by al-Qazwīnī.[19] In the following two sections some of the Greek accounts will be given for the Ptolemaic constellations which overlaid the earlier Bedouin ones. For these Greek sources the writings of Aratus and early poets such as Homer and Hesiod have been consulted and cited, as well as the considerable number of secondary sources concerned with Greek star names.[20]

In the two subsequent subsections of this part of the study the lunar mansions and the 48 constellations will be discussed in detail. The lunar mansions are treated separately from the constellations because they are not part of the Ptolemaic constellation outlines, but are inscribed at regular intervals along the ecliptic. Furthermore, additional comments are required for background to the complex subject of lunar mansions. In the section on the "Constellations" in this chapter, each constellation will be discussed in terms of the star names appearing on the Smithsonian globe. The order of the constellations will be the order given by Ptolemy and in all derivative Islamic star catalogs. When a star is described as being a particular number in a constellation, this again refers to numbering in the al-Ṣūfī and Ulugh Bēg catalogs. The minor differences in their numbers, when pertinent, will be noted. Minor spelling errors on the part of the maker and inconsistencies in genitive constructions will not be noted (see Chapter 3). References to other globes when comparing terms or images will be by the catalog numbers given in Chapter 6. Arrows are placed on the photographs to designate plugs or other special features, in order to distinguish the plugs from stars. Compass directions have been noted on each photograph of the individual constellations so that proper orientation can be maintained. Descriptions of the figures will be given in terms

of the direction of the compass rather than right or left to avoid confusion.

The unequivocal modern identification of a star is not always possible and modern writers occasionally disagree on this. Generally Kunitzsch's identification has been followed,[21] but sometimes that of Peters and Knobel or Baily was used. Quite frequently the number of the star in the al-Ṣūfī star catalog is given just before the modern identification. The nomenclature for the latter is for the most part that of Bayer, employing Greek letters, and when necessary lower case Latin letters, followed by the genitive of the Latin name for the constellation. Occasionally a star not covered by the Bayer system is designated by a Flamsteed number (abbreviated Flam.).

LUNAR MANSIONS

The origin of the system of lunar mansions is obscure, with at least four theories having been put forward regarding the matter. It has been suggested that it began with the related Chinese system called *hsiu* and spread from China to India and the Near East.[22] The Indian system called *nakṣatra* of 27 or 28 junction-stars has also been mentioned as the original source.[23] Others have contended that it was Babylonian in origin and extended thence to India, China, and Arabia,[24] or that Hellenistic astronomy played a role in the diffusion either as a point of origin or through Hellenistic astronomical and trigonometric techniques current in India.[25] It is fairly evident that the Arabic version is an accretion of the Indian upon an earlier Bedouin grouping of fixed stars, applying the traditional Bedouin star names to the Indian lunar mansions dividing the zodiac.

The Bedouins on the Arabian peninsula in pre-Islamic times were chiefly nomadic camel owners and herders of goats who needed to estimate the passage of time and to predict meteorological events so as to locate winter and spring grazing lands whose locations varied greatly depending upon the rainfall.[26] These early Arabs had a primitive system called *anwāʾ* based on a series of 28 prominent star groups. The solar year was then divided into 28 intervals, each marked by observing the star group that set in the West at dawn (i.e., cosmical setting called *raqīb*) and the star group that rose in the East with the sun (i.e., heliacal rising, called *nawʾ*).[27] Naturally these two asterisms were opposite each other in the heavens and in the *anwāʾ* sequence of 28 star groups. The stars themselves were held responsible for weather conditions; thus the early Bedouins could attempt to predict the weather and mark the passage of time.

Sometime before the advent of Islam the Bedouins assimilated from India a system of 27 or 28 "stations" or "mansions" of the moon, called in Arabic *manāzil* (singular *manzil*).[28] The mansions corresponded to places in the sky through which the moon passed in its course from new moon to new moon in 27 or 28 nights. The course of the moon is inclined to the ecliptic at an angle only slightly more than 5°, but its brilliance is such that nearby stars cannot be observed. For this reason the mansions were named for stars in the vicinity of but not directly along the ecliptic. Each mansion came to represent approximately one day's travel of the moon and therefore corresponds to roughly 13° along the ecliptic beginning at the vernal equinox. According to al-Bīrūnī,[29] it seems that by the time the system was assimilated in pre-Islamic Arabia the system of *manāzil* had come to be more frequently associated with intervals of the ecliptic beginning with the vernal equinox than with the original 27 or 28 junction-stars or asterisms that gave them their names.

The resulting *anwāʾ-manāzil* system began with a star group in Aries (probably to be identified with $\beta\gamma$ *Arietis*), which corresponded to the first segment of the House of Aries near the vernal equinox about 300 BC. These two systems are not, however, entirely compatible, for one is calculated on the basis of the risings and settings of fixed star groups and the other reckoned on regular intervals of the ecliptic taken from the vernal equinox. With the precession of the equinoxes no fixed star will long maintain the same distance from the vernal equinox. Consequently one star group cannot be successfully aligned with one segment of the ecliptic measured from

the vernal equinox for an extended period of time.

This attempted compounding of *anwāʾ* and the lunar mansions (*manāzil*) gave rise to a type of Arabic literature known as *anwāʾ* literature, in which lexicographers, such as Ibn Qutaybah, born in Iraq in AD 828,[30] attempted to record the Bedouin association of meteorological phenomena with the *anwāʾ* star groups associated with the 28 lunar mansions. Such works would usually contain an explanation of the *anwāʾ* star groups and lunar mansions, the dates of the beginning of visibility in the east in the morning of each star group, and an explanation of the system of rains, winds, cold, and other weather conditions associated with these risings, illustrated with appropriate proverbs, poetry, and folklore.[31] A second type of literature concerned with the *anwāʾ-manāzil* system was arranged in the form of a calendar and enumerated natural, celestial, and meteorological events of concern to peasants and herdsmen.[32]

About the same time that the lexicographers were recording this Bedouin material in the ninth century AD, the first listing of these 28 mansions by an Arabic astronomer was made by al-Farghānī.[33] Astrologers also became seriously interested in the division of the zodiac into lunar mansions and the assignment of good or ill characteristics to each. In the tenth century al-Ṣūfī used much of the *anwāʾ* literature recorded by the lexicographers for his discussion of the fixed stars, and identified these star groups in terms of the stars cataloged by Ptolemy.

In the eleventh century al-Bīrūnī presented in his *Chronology of Nations*, a lengthy discussion of lunar mansions. In this work he criticizes the traditional Arab use of the rising and setting of star groups to determine the mansions, which cannot remain accurate because of the precession. When criticizing the practice of an astronomer of Rayy in Persia, al-Bīrūnī says:

> That the truth is the very reverse of his theory, that the nature and peculiarities which are attributed to the first Station [Mansion], and that which the Hindus relate of the connection of this Station with others, are peculiar to the first part of [the House of] Aries, and never leave this place, although the star or stars which form the Lunar Station may leave it. In a similar way, all that is peculiar to Aries does not move away from the place of [the House of] Aries, although the constellation of Aries does move away.[34]

Al-Bīrūnī then outlines a modification of the *anwāʾ-manāzil* system, which he considered better since it is not affected by the precession of the equinoxes. It became the system used in most astrological prognostication. Each House or 30° interval of the zodiac is divided into two and one-third lunar mansions. A rising of a lunar mansion means that the sun is in that particular segment of the zodiac, while the second mansion preceding it rises in the east between the beginning of dawn and the rise of the sun. That is to say, since the sun's brightness makes it impossible to see the actual rising of a lunar mansion occupied by the sun, the observer notes, between the beginning of dawn and the appearance of the sun, the rising of the second mansion preceding the lunar mansion interval in the established sequence. For example, the third lunar mansion is said to be rising if the first mansion is the last one whose rising is visible before the sun rises.

The order of succession of the mansions is the same as that of the zodiac, that is from one to the one east of it. For example, *sharaṭayn* to *buṭayn*, Pleiades to Aldebaran. The term *nawʾ*, which applies to the rising of a lunar mansion is also given to the influence of its cosmical setting, which occurs at a six-month interval from its rising. The intervals of the ecliptic designated as lunar mansions are of such a length that the sun remains in each for approximately 13 days, though there is some slight variation since the length of mansions is not totally uniform. Each lunar mansion was given the name attributed to one of the 28 *anwāʾ* star groups, even though the segments of the zodiac were no longer in close proximity to that *anwāʾ* group.

On the Smithsonian globe the names of the lunar mansions are written at intervals along the ecliptic of about 13°, indicated by a small dash at right angles to the ecliptic. This clearly indicates that the globe was made in a tradition which interpreted the *anwāʾ-manāzil* system as segments of the zodiac, and not in the earlier man-

ner in which the rising of the star groups themselves was the the determining factor. In most of the Islamicate astronomical-astrological literature the 28 lunar mansions are numbered with the first corresponding to the vernal equinox, and the second one occurring about 13° later further into the zodiacal House of Aries. On the Smithsonian globe the first lunar mansion in the usual order (*sharaṭayn*) is placed at 13° House of Aries, while the twenty-eight (*rishāʾ*) is at the vernal equinox. This identical arrangement is also to be found on globe No. 11, made by Qāʾim Muḥammad of the Lahore workshop, probably the same maker who produced the Smithsonian globe. On other globes, such as No. 74, No. 60 (Figure 7), and No. 59 (the earliest of the Class B globes dated 535 H/AD 1140–1141), the usual order of having *sharaṭayn* at the vernal equinox is maintained. There was also a tradition in Islamicate and in later Latin treatises of associating with the lunar mansions abstract patterns of dots or stars in small geometrical designs frequently having little to do with the actual conformation of the original asterisms.[35] One extant Islamicate globe (No. 60, see Figure 7) dated 718 H/AD 1318–1319 and signed by ʿAbd al-Raḥmān ibn Burhān al-Mawṣilī (authenticity questionable), represents the lunar mansions by similar patterns of inlaid silver dots along the ecliptic, apparently in this same tradition.

Many of the Arabic terms applied to the lunar mansions were so ancient by the time the lexicographers recorded them in the ninth century that their significance had been lost even at that time. For this reason only a tentative translation can frequently be given. The names appear to be older than many of the other traditional Arabic pre-Islamic star names, and the imagery behind them more obscure, often apparently coming from a very ancient poetry.[36] In the following descriptions each lunar mansion will be given in the commonly accepted order, with the position along the ecliptic where it is engraved on the Smithsonian globe. At the end of the discussion of each mansion the position according to al-Bīrūnī[37] will be given for comparison with that on the Smithsonian globe. See the photographs of the corresponding zodiacal houses in the subsequent section for illustrations of the distribution of the lunar mansion names along the ecliptic.

Lunar Mansion 1. *Sharaṭayn*

(Engraved at 13° House of Aries)

The word *sharaṭ* can mean "sign" or "signal" or "the beginning of a thing," and *sharaṭayn* means "the two *sharaṭ*." Al-Qazwīnī (Ideler, 134) says the two stars of this lunar mansion are named "the two signs" because they mark the beginning of the new year. Among the Bedouins these two stars were also called *qarnā al-ḥamal* (the horns of the ram), referring to an older indigenous concept of a young ram that was not the same as the Ptolemaic form of Aries. Ibn Qutaybah says this lunar mansion was also called *al-naṭḥ*, *al-nāṭiḥ*, or *al-naṭīḥ*, all meaning the act of butting (Kunitzsch [1961], nos. 197–200). Al-Ṣūfī (*Ṣuwar*, 142), however, was understandably confused by the two traditions and at one point equated the lunar mansion *sharaṭayn* with the two bright stars on the horns of the Ptolemaic ram Aries, nos. 1 and 2 [$\beta\gamma$ *Arietis*] (see Kunitzsch [1961], no. 286). Al-Ṣūfī also said another tradition indicated that the "two signals" were made up of one of the two on the horns of Aries (no. 1) and the first unformed star of Aries, at the top of the head [α *Arietis*]. Al-Bīrūnī (*Chron.* [trns.], 343) says that sometimes three stars are included in the mansion [$\alpha\beta\gamma$ *Arietis*] in which case it was usually called *al-ashrāṭ*, which is the plural instead of the dual of *sharaṭ*. Al-Bīrūnī gives as the position of this mansion along the ecliptic 0° House of Aries, i.e., the vernal equinox.

Lunar Mansion 2. *Buṭayn*

(Engraved at 25½° of the ecliptic)

The name means "the small belly," being as al-Bīrūnī points out a diminutive form of *baṭn* (belly), so as to contrast with the twenty-eighth lunar mansion, sometimes called "the belly of the

fish." Al-Ṣūfī (*Ṣuwar*, 142) adds that it is sometimes called simply *baṭn*, while some *anwāʾ* authors (Kunitzsch [1961] no. 63) called it *baṭn al-ḥamal* (the belly of the ram).

There is not complete agreement on the identification of the stars comprising the second lunar mansion with those of the Ptolemaic catalog. Al-Ṣūfī and later al-Bīrūnī identify *al-buṭayn* with three stars that form a triangle in the Ptolemaic Aries: one near the outgrowth of the tail (no. 7), the first of the three in the tail (no. 8), and one on the back of the thigh (no. 11), which are εδρ *Arietis*, respectively. Al-Ṣūfī also says that some *anwāʾ* authors (Kunitzsch [1961], no. 68) align this mansion with four stars to the west of *al-mankib*, the star on the shinbone of the Ptolemaic Perseus [ξ *Persei*] or according to some, the two on the lower foot [οζ *Persei*]. These four stars would, according to al-Ṣūfī, be nos. 2–5 of the unformed stars of Aries, the four over the rump of Aries near Perseus (Flam. 41, 39, 35, 36 *Arietis*). Al-Bīrūnī gives the position of the second lunar mansion as 12°51′26″ of the House of Aries.

Lunar Mansion 3. *Thurayyā*

(Engraved at 38½° of the ecliptic)

The third lunar mansion is named for the famous open star cluster called the Pleiades located in the Ptolemaic constellation of Taurus, of which six or sometimes seven stars are visible with the naked eye. The Arabic name *al-thurayyā* is a very old Arabic star name whose origin and etymology are obscure (see Hommel, 595; Kunitzsch [1961], no. 306). Al-Ṣūfī (*Ṣuwar*, 151) says that they called it *al-thurayyā* (possibly translatable as "the precious gem") because the Arabs were blessed by these stars and their risings. The word *thurayyā* can also mean "lustre," and comes from a root meaning "to be abundant" or "to increase." Al-Bīrūnī (*Chron.* [trns.], 343) says "some people maintain they were called so because the rain, which is brought by their *nawʾ*, produced *tharwa*, i.e. abundance."

In both the *Iliad* (XVIII, 486) and the *Odyssey* (V, 272), Homer mentions the Pleiades (πλειάδες). His near contemporary, Hesiod (*Works and Days*, 615, 383), states that the cosmical setting of the Pleiades in the Fall was a time for sowing and rough seas, while their heliacal rising in the Spring was a time for harvest and the beginning of the sailing season. Hesiod adds that they are the daughters of Atlas, for the Pleiades were commonly held to be the daughters of Atlas by Pleione, hence the name Pleiades; another etymology put forward in classical literature was that the word Pleiades came from πλεῖν (to sail). Aratus (lines 253–268) gave the names by which the poets know the seven small stars: Alcyone, Merope, Celaeno, Electra, Sterope, Taygete, and Maia, but adds that only six can be observed (lines 254–255). Hipparchus (*Comm. arat.*, I, 6.14) criticizes Aratus for this statement, saying that on a clear moonless night a person can observe seven stars. In the work attributed to Eratosthenes (*Catast.*, 14 and 23) the legend is put forward of seven stars, one of which is obscure (ἀφανής) because six of the daughters of Atlas and Pleione mated with immortals, while the seventh, Merope, was wife to the mortal Sisyphus and through repentance hides from sight. The Latin poet Hyginus in his *Astronomica* (II, 21) gives an additional story that the obscure star might be the daughter Electra who does not appear because of grief over the fall of Troy. This myth of the "lost Pleiad" was repeated by Ovid (*Fasti*, IV, 170–178) and others. (For a history of the legend of the Pleiades and the "lost Pleiad" see Martin [1956] 72–79 and 89–94.)

Even though the poetical and literary sources available in Greece, as well as the one extant work of the astronomer Hipparchus, clearly show a knowledge of six or seven Pleiades, Ptolemy nonetheless lists only four stars as comprising the Pleiades in his catalog (nos. 30–33 of the constellation Taurus). Al-Ṣūfī and Ulugh Bēg both followed Ptolemy in listing only four Pleiades in their catalogs. Al-Ṣūfī, however, explained clearly that there were two or three additional stars nearby (see the discussion of Figure 64 for al-Ṣūfī's statement and a discussion of the Pleiades on the Smithsonian globe). Al-Bīrūnī, on the other hand, said specifically that *al-thu-*

rayyā (the Pleiades) consisted of six stars close together, resembling a bunch of grapes, incorrectly called seven by the poets (*Astrol.*, sec. 164). Al-Bīrūnī (*Chron.* [trns.], 343–344) added that "Ptolemy mentions only four stars of the Pleiades since he had not observed more of them, because to eye-sight they seem to lie quite close together."

In some *anwāʾ* literature the Pleiades were called *alyat al-ḥamal* (the tail of the ram). This title appears to refer to an early Bedouin concept of a ram that differed in outline from the Ptolemaic Aries (see Kunitzsch [1961] no. 9; al-Bīrūnī, *Chron.* [trns.], 343), and which was displaced by the introduction of the Greek constellations into the Islamic world. Al-Ṣūfī seems, however, to be aware only of the Ptolemaic Aries and criticizes the *anwāʾ* authors for using such a term in reference to the Pleiades.

In the Bedouin tradition, however, *al-thurayyā* (the Pleiades) was most commonly associated with the head of a woman (also named *al-thurayyā*) who had one arm passing through the area of Perseus (Figure 57) with a henna-stained hand in Cassiopeia (Figure 56). Her other hand was in the area to the southwest where the head of Cetus is now visualized (Figure 75).

In keeping with this image of a woman, many other stars were given special names by the early Bedouins. Thus we have the following star names:

In the shoulder-blade of *al-thurayyā* (*ʿātiq al-thurayyā*) are two stars on the lower foot of the Ptolemaic Perseus, which according to al-Ṣūfī are nos. 25 and 26 of Ptolemy's list [*oζ Persei*]. Ibn Qutaybah says it is one "not bright" star between *al-thurayyā* and the shoulders, which for him are the two in the lower foot of Perseus; to this interpretation al-Ṣūfī objects (see Kunitzsch [1961], no. 41).

According to al-Ṣūfī "the shoulder [of the extended right arm] of *al-thurayyā*" (*mankib al-thurayyā*) is the star in the shinbone of the lower leg of Perseus, immediately above the two comprising the shoulder-blade. Al-Ṣūfī identifies the star with no. 24 of Ptolemy's catalog [*ξ Persei*]. Ibn Qutaybah says, however, "the shoulder" consisted of two stars identified as *oζ Persei*, that is, the two on the foot, which al-Ṣūfī had called "the shoulder-blade" (Kunitzsch [1961], no. 157).

"The upper arm of *al-thurayyā*" (*ʿaḍud al-thurayyā*) is for both al-Ṣūfī and Ibn Qutaybah the row of three stars, two of which are in the upper leg and thigh closest to the ogre's head, and the third one the most northern of the three small stars on the stomach of Perseus. Al-Ṣūfī identifies these as nos. 10, 22, and 23 of Perseus [*δνε Persei*]. This group is not labeled on the Smithsonian globe.

The elbow of the outstretched arm of *al-thurayyā* (*mirfaq al-thurayyā*) is the large star in the stomach of Perseus (no. 7 of the constellation [*α Persei*]). The middle of the three small stars on the stomach of Perseus is called traditionally *ibrat al-mirfaq* (the point of the elbow of *al-thurayyā*), which is aligned by al-Ṣūfī with no. 9 of Perseus [*ψ Persei*]; it is not labeled on the Smithsonian globe.

The last and lowest of the three small stars close together on the stomach of Perseus is called *maʾbiḍ al-thurayyā* (the fatty part [of the upper arm] of *al-thurayyā*). Al-Ṣūfī knew only one star by that name, and identified it as no. 8 of Perseus [*σ Persei*]. Ibn Qutaybah, on the other hand, saw two stars in that area standing near one another, between which was an estimated visual distance of one *dhirāʿ*, which for al-Ṣūfī was about 2°20′ (See Kunitzsch [1961] no. 152). This label does not appear on the Smithsonian globe.

The forearm, *sāʿid al-thurayyā*, was made up, according to al-Ṣūfī, of the star in the upper arm of the arm raised above Perseus's head and the large star immediately below on the chest, which al-Ṣūfī identified with nos. 2 and 3 of the constellation [*ηγ Persei*]. Ibn Qutybah, however, saw three stars as the forearm, which he called *al-dhirāʿ* (forearm or cubit), instead of *al-sāʿid* (Kunitzsch ([1961], nos. 81 and 258). These three stars were between the elbow and the wrist, perhaps including the small star in the beard of Perseus on the Smithsonian globe [no. 5 of Perseus; *τ Persei*]. This label also does not appear on the Smithsonian globe.

The wrist of the right outstretched arm is called *miʿṣam al-thurayyā*, and is represented by

the two open star clusters marked as one star in the hand of Perseus over his head [χh *Persei*]. See the discussion of Perseus and Figure 57 for further details.

The hand of the right arm was visualized as spreading out from the wrist (hand of Perseus) toward Cassiopeia, with the fingers being represented by the five bright stars of Cassiopeia forming the well-known W-shaped asterism. This hand was called *al-kaff al-khaḍīb*, that is, a hand dyed with henna (*ḥinnāʾ*), a red dye made from *Lawsonia inermis*. The expression "the dyed hand" referred originally to five stars (nos. 12, 2, 4, 5, 6 of the Ptolemaic catalog [βαγδε *Cassiopeiae*]; see Figure 56). However, as al-Ṣūfī noted (*Ṣuwar*, 77) it sometimes happened that astronomers would take a name originally used for a group of stars and apply it to only one of them; in this case it was applied to no. 12, the star on her back elbow [β *Cassiopeiae*], as a star for use on astrolabes. For this reason the label on the Smithsonian globe appears to apply to only that one star rather than the entire group of five.

The other hand of their early conception of a female figure centering around the Pleiades is found in the head of the Ptolemaic constellation Cetus, the sea monster or whale (see Figure 75). It is called *al-kaff al-jadhmāʾ* (the cut-off hand) probably because no star groups connect the hand with *al-thurayyā*, the Pleiades, representing the head. Al-Ṣūfī identifies the cut-off hand with the first six stars of the constellation Cetus [λαγδνμ *Ceti*].

To the third lunar mansion, *al-thurayyā*, al-Bīrūnī assigned the position of 25°12′50″ in the House of Aries.

Lunar Mansion 4. *Dabarān*

(Engraved at 51½° of the ecliptic or 21½° House of Taurus)

Al-Dabarān is from a root meaning "to follow," and refers to the fact that it follows the Pleiades, for which reason it was sometimes called *tālī al-najm* "the follower of The Star," since the Pleiades were occasionally called "the star" (*al-najm*). Al-Ṣūfī and the *anwaʾ* authors (Kunitzsch [1961], no. 69) referred to *al-dabarān* as a large bright red star that corresponded to the one in the eye of the Ptolemaic constellation of Taurus, no. 14, which is the famous star α *Tauri*, called today Aldebaran (see Figure 64). Aldebaran is the most prominent of the open cluster composing the asterism of the Hyades.

The Bedouins also called the star comprising the fourth lunar mansion *al-fanīq* (the camel-stallion), while the stars around it (the other Hyades) were called *al-qilāṣ* (the young camels; see al-Bīrūnī, *Chron.* [trns.], 344). Al-Bīrūnī gives the position of the fourth lunar mansion as 8°34′18″ of the House of Taurus, which is 38°34′18″ from the vernal equinox.

Lunar Mansion 5. *Haqʿah*

(Engraved at 63° of the ecliptic, or 3° House of Gemini)

The word *haqʿah* means a tuft of hair, a branding mark usually on the neck or breast of a horse, or any other distinguishing mark of a horse. Al-Bīrūnī said the stars of this lunar mansion were called *haqʿah* because they were compared with a circles of hairs on the leg of a horse near the foot; a horse having such a distinguishing mark was called *mahqūʿ* which is from the same root as *haqʿah*. This lunar mansion was said to correspond to the first star of the Ptolemaic constellation of Orion. In his catalog Ptolemy clearly considered this to be a single nebulous (νεφελοειδής) star in the forehead of Orion, while the *anwāʾ* authors (Kunitzsch [1961], no.115a), al-Ṣūfī (*Ṣuwar*, 268), and al-Bīrūnī (*Chron.* [trns.], 344) saw three small stars next to one another like a small triangle [$\lambda\varphi^1\varphi^2$ *Orionis*]. These stars were sometimes also called *al-athāfī* (a three-legged support for a cooking pot) because they resembled such a tripod. Al-Ṣūfī adds that the three stars were occasionally called *haqʿat al-jawzāʾ*, the tuft of hair or distinguishing mark of *jawzāʾ* (the Bedouin name for a giant, possibly feminine), visualized in the area we consider occupied by the Ptolemaic constellations of Orion and Gemini. (See the discussion of Orion [Figure 76], and the section on "Classical Greek and Pre-Islamic Sources.")

Al-Bīrūnī gives the position of the fifth lunar mansion as 21°25′44″ of the House of Taurus, or 51°25′44″ from the vernal equinox.

Lunar Mansion 6. *Hanᶜah*

(Engraved at 77° of the ecliptic, or 17° House of Gemini)

The root of this word can mean either to fold or bend, or to brand a camel on the neck. It is from the former meaning that al-Bīrūnī (*Chron.*, 344) derived his explanation of the word "as if each of them were winding and twining round the other." *Hanᶜah* is more often translated as a brand on a camel's neck, maintaining a parallel with the fifth mansion, and was traditionally applied to two stars (nos. 17 and 18 of the Ptolemaic constellation of Gemini [$\gamma\xi$ *Geminorum*]; see Figure 65). These two stars mark the feet of the more southern of the two twins. Both *hanᶜah* and *haqᶜah* (the sixth and fifth mansions) are in the area of the sky called *al-jawzāᵓ* by the Bedouins, which covered the area of Ptolemy's Orion and part of Gemini, and seems to have been a giant form, possibly feminine. The star γ *Geminorum*, whose modern name is Alhena from the name of the sixth mansion, was also commonly called *al-zirr*, which has many meanings including button, socket of the thigh, a pivot, or a bud of a plant; the intent is obscure. The second star [ξ *Geminorum*] bore the additional title of *al-maysān* (a bright star). The traditions regarding these two names are not uniform (see Kunitzsch [1961], no. 321).

Some people in the *anwāᵓ* tradition called the three stars standing before $\gamma\xi$ *Geminorum* (the three in the feet of the northern twin [nos. 14, 15, 16; $\eta\mu\nu$ Geminorum]) *al-taḥāyī*, whose precise spelling is not uniform nor its meaning clear. They then termed all five stars together *al-hanᶜah* (Kunitzsch [1961], nos. 114, 296). Some, however, interpreted *al-taḥāyī* (or *al-taḥiyyāt* or *al-taḥiyyah* as it sometimes was written) as the name of the three comprising the fifth lunar mansion, *al-haqᶜah* (al-Ṣūfī *Ṣuwar*, 166–167).

Al-Ṣūfī also states that the five stars in the feet of the twins were called *qaws al-jawzāᵓ* (the bow of *al-jawzāᵓ*) which he throws at the foreleg of the lion. The anterior of the two forelegs of the huge lion of the early Bedouin traditions was formed by the two bright stars in the heads of the Ptolemaic Gemini; this foreleg constituted the seventh lunar mansion.

It is possible that at one time *hanᶜat al-jawzāᵓ* and *haqᶜat al-jawzāᵓ* were combined into one lunar mansion (see Hommel, 601–602). Al-Bīrūnī gives *hanᶜah* the position of 4°17′11″ House of Gemini, or 64°17′11″ from the vernal equinox.

Lunar Mansion 7. *Dhirāᶜ*

(Engraved at 90° of the ecliptic, or 0° House of Cancer, at the point of the summer solstice)

"The foreleg" (of the lion) was a name applied to the two stars in the heads of the Ptolemaic Gemini [$\alpha\beta$ *Geminorum*]. In the *anwāᵓ* tradition these two stars were seen as forming one of the forelegs of an enormous lion, which covered an area of the heavens much larger than the Ptolemaic Leo. The lunar mansions numbered 7–11 and 14 all reflect the image of this large lion.

The traditions were confused as to whether the "foreleg" formed by the two stars in Gemini was the "drawn up" leg (*al-maqbūḍah*) and the other foreleg, which was formed by the two stars of Canis Minor [$\alpha\beta$ Canis Minoris] was the "extended" leg (*al-mabsūṭah*), or whether it was the other way around. There was, moreover, disagreement as to which of these two groups of stars, those in Gemini or those in *Canis Minor*, constituted the lunar mansion. Authors frequently confused these names (Kunitzsch [1961], no. 83); al-Bīrūnī (*Chron.* [trns.], 345) adds that some interpreted the *dhirāᶜ* or seventh lunar mansion as being the two Sirii, that is Sirius [α *Canis Majoris*] and Procyon [α *Canis Minoris*].

Al-Ṣūfī (*Ṣuwar*, 165) astutely and logically argues that the groups of stars that rise first should be the "extended" leg. Since the northern *dhirāᶜ* [$\alpha\beta$ *Geminorum*] rises before the southern *dhirāᶜ* [$\alpha\beta$ *Canis Minoris*], the former rightly should be termed "the outstretched" and the latter "the

drawn up." In addition al-Ṣūfī argued that since the northern *dhirā*ᶜ [*αβ Geminorum*] was closer to the ecliptic it must be the lunar mansion. Al-Bīrūnī gives the position of the seventh lunar mansion as 17°18′35″ of the House of Gemini, which is 77°18′35″ from the vernal equinox.

Lunar Mansion 8. *Nathrah*

(Engraved at 103° of the ecliptic, or 13° House of Cancer)

Al-nathrah means "the cartilage of the nose," belonging to the image of the large lion of Bedouin tradition. Al-Bīrūnī (*Chron.* [trns.], 345; *Astrol.*, sec. 164) applies this name, apparently using it in the broader sense of nose, to three stars in a row on the back of the Ptolemaic constellation of Cancer, the outside two stars being *γδ Cancri* and the middle one the open cluster M44, called *Praesepe* or the Beehive, which was considered in both the Greek and Arabic traditions to be nebulous.

Al-Ṣūfī, on the other hand, uses the word *nathrah* only for "the smudge (*laṭakhah*) which resembles a bit of a nebula"—that is, for *Praesepe*, which was considered the first star of the constellation of Cancer. The two stars on either side [*γδ Cancri*] he said (*Ṣuwar*, 173) were called *al-mankharān* (the two nostrils); the "smudge" in between was also named *al-mukhaṭah* (the mucus). The three stars together, according to al-Ṣūfī, were traditionally called *fam al-asad* (the mouth of the lion). Al-Bīrūnī and al-Ṣūfī record that this open cluster M44 was also traditionally called the uvula (*al-lahāh*) of the large lion. The position given by al-Bīrūnī for the eighth mansion is 0°0′0″ of the House of Cancer, or the point of the summer solstice.

Lunar Mansion 9. *Ṭarf*

(Engraved at 115¾° of the ecliptic, or 25¾° House of Cancer)

The word *ṭarf* means the vision or glance (also of the large lion). It was applied by al-Ṣūfī (*Ṣuwar*, 173, 181) to two stars: the second formed star of the Ptolemaic Leo, which is the lower of the two on the mouth [*λ Leonis*], and the second unformed star of Cancer [*κ Cancri*]. This tradition was also followed by al-Bīrūnī (cf. Kunitzsch [1961], no. 304a; Hommel, 602). Navigators designated the two stars *ᶜayn al-asad*, "the eye of the lion" (Kunitzsch [1961], no. 46a). Al-Bīrūnī assigned the position of 12°51′26″ House of Cancer, or 102°15′26″ of the ecliptic, to the ninth lunar mansion.

Lunar Mansion 10. *Jabhah*

(Engraved at 128½° of ecliptic, or 8½° House of Leo)

Al-jabhah (forehead), sometimes called *jabhat al-asad* (the forehead of the lion), was a name applied to four stars collectively and referred to the forehead of the large lion of the Bedouin tradition (Kunitzsch [1961], nos. 103a, 103b). These four stars are the two on the shoulder of the Ptolemaic Leo (nos. 5 and 6), the one to the southwest (no. 9), and the large star on the upper part of the front leg of Leo (no. 8 called Regulus; see Figure 67). These are *ζγηα Leonis*, respectively. The position of the tenth mansion, according to al-Bīrūnī, should be 25°12′52″ of the House of Cancer or 115°12′52″ from the vernal equinox.

Lunar mansions seven through ten were also commonly called *kilāb al-shitā*ᵓ (the dogs of the winter or rain) (Kunitzsch [1961], no. 147).

Lunar Mansion 11. *Zubrah*

(Engraved at 141½° of ecliptic, or 21½° House of Leo)

Al-Ṣūfī says (*Ṣuwar*, 181) of *zubrat al-asad* that it is "the mane of the lion, that is, his withers and shoulders" and identifies the mane of the large lion as nos. 20 and 22 of the Ptolemaic Leo [*δθ Leonis*], which are the large star on the rump of Leo and the star at the top of the thigh (see Figure 67). See al-Bīrūnī (*Chron.* [trns.], 346) for further explanation of the word *zubrah.*

These two stars were also called *al-kharātān*, whose meaning is unclear; al-Ṣūfī says the singular is *kharā*, so that *al-kharātān* would mean the two *kharā*. Al-Bīrūnī apparently takes the word from the root *khrt*, meaning to pierce with a hole, for he says they are called the *kharātān* "as if each of them were penetrating into the interior of the lion" (cf. Hommel, 603 note 2; Kunitzsch [1961], no. 128).

Al-Bīrūnī assigns the tenth mansion the position 8°31′18″ of the House of Leo, or 128°31′18″ from the vernal equinox.

Lunar Mansion 12. *Ṣarfah*

(Engraved at 154¼° of ecliptic, or 4¼° House of Virgo)

The term *ṣarfah* (change [of weather]) was applied to a bright star behind the eleventh lunar mansion; al-Ṣūfī identified the star as the one in the tail of the Ptolemaic Leo, no. 27 [*β Leonis*]. The star was called *ṣarfah*, according to al-Ṣūfī (*Ṣuwar*, 181) and al-Bīrūnī (*Chron.* [trns.], 347) because of the change in the weather from heat with its rising at dawn before the sun and the change from cold weather with its setting at dawn. As part of the image of the larger lion of the Bedouin tradition, this star was called "the seed of the lion" (*qanb al-asad*) according to al-Ṣūfī, who added by way of explanation "that is to say, his scrotum" (*wiʿāʾ qaḍībihī*). The tail of the large Bedouin lion was formed by the stars of the Ptolemaic Coma Berenices, called in Arabic *al-hulbah*, meaning the coarse hairs at the end of the tail. Al-Bīrūnī assigned the position of 21°25′44″ House of Leo, or 141°25′44″ from the vernal equinox, to the twelfth mansion.

Lunar Mansion 13. *ʿAwwāʾ*

(Engraved at 167¼° along ecliptic, or 17¼° House of Virgo)

The meaning of the name *ʿawwāʾ* is uncertain, but it appears to be from a root meaning to howl or yelp, or to twist or bend. According to al-Ṣūfī the name was applied to five stars in the Ptolemaic constellation of Virgo, which formed roughly a 90° angle (see Figure 68). These five are the one at the top of the southern wing, the one on the southern shoulder, the one at the side of the waist nearest the ecliptic, the large one in the middle of the waist, and the large one on the northern wing near the elbow, nos. 5, 6, 7, 10, and 13, respectively [*βηγδε Virginis*]. Al-Ṣūfī (*Ṣuwar*, 193) adds, however, that some people omitted no. 10, the one in the middle of the waist [*δ Virginis*] and thus recognized only four stars in the thirteenth lunar mansion.

Al-Bīrūnī (*Astrol.*, sec. 164) follows the latter tradition of four stars and accounts for the name *ʿawwāʾ* by saying that the Arabs spoke of dogs barking behind the large lion, thus interpreting *ʿawwāʾ* as howling. Al-Ṣūfī too had mentioned that some saw four or five dogs here following the lion, and also added that the lunar mansion was sometimes called *ʿawwāʾ al-bard* "the *ʿawwāʾ* of the cold." The tradition of five stars, however, al-Bīrūnī presents in another writing (*Chron.* [trns.], 346, 351) where he takes *ʿawwāʾ* to mean "to turn" because they are five stars in a line, the end of which is turned to form the 90° angle. See Hommel (604 note 1) and Kunitzsch [1961], no. 44 for further information on the meaning of *ʿawwāʾ*. Al-Bīrūnī gives the thirteenth mansion the position of 4°17′10″ in the House of Virgo, or 154°17′10″ from the vernal equinox.

Lunar Mansion 14. *Simāk*

(Engraved at 180° of ecliptic, or 0° House of Libra, at the autumnal equinox)

Two stars each bear the name *simāk:* the large star on the southern hand of Virgo [*α* Virginis; Spica] and the large star at the hemline of Boötes [*α Boötis*; Arcturus], which is due north of Spica (see Figures 53 and 68). The name *simāk* is of ancient, perhaps Babylonian, origin. Its meaning has been obscured with time; hence it is impossible to give it an intelligible translation (see Hommel 595–596; Gundel & Böker, cols. 509–522; al-Bīrūnī, *Chron.* [trns.], 347). These two stars, each called *simāk*, formed the two hind legs

of the large lion visualized in the *anwāʾ* tradition. Only the one in Virgo, however, constituted a lunar mansion. The full name of this star was *al-simāk al-aʿzal* (the unarmed *simāk*), which distinguished Spica from Arcturus, which bore the title *al-simāk al-rāmiḥ* (the armed *simāk*). Arcturus was considered "the armed simak" because there are stars near it forming a lance or weapon, while no such weapon was seen to accompany Spica. As a lunar mansion rather than a star, however, Spica was mostly referred to simply as *al-simāk*. The fourteenth lunar mansion is given the position of 17°8′35″ of the House of Virgo, or 167°8′35″ from the vernal equinox.

Lunar Mansion 15. *Ghafr*

(Engraved at 193° along ecliptic, or 13° House of Libra)

The meaning of the name *al-ghafr* is not at all clear; it was applied to three stars in the Ptolemaic constellation Virgo: the star in her foot nearest the ecliptic and the two at the hemline, nos. 22, 23, and 25, [ικλ *Virginis*]. Al-Bīrūnī (*Astrol.*, sec. 164) states that only the two stars on the hemline (*dhayl*) constitute the lunar mansion, while elsewhere (*Chron.* [trns.], 347) he has the more common tradition of three inconspicuous stars.

Many etymologies are presented in the Arabic astronomical literature for the word *ghafr*, the most common being that the name was applied because the stars were inconspicuous. Al-Ṣūfī (*Ṣuwar*, 194) in his discussion of Virgo says of this mansion "they also say that it is called *al-ghafr*, for, because of the imperfection of the light of its stars, they say it was veiled (from the root *ghfr*)—that is, it was obscured." Shortly thereafter he continues "they also say it is called *al-ghafr* because it is above the two claws of the scorpion, and for this reason it is called *al-mighfar* (the helmet) which is over the head of a man." Another derivation is that the root means to have a covering of hair, that is, it is seen as the coarse hair which is at the tip of the lion's tail. This explanation, however, shows confusion in the use of the star names, for the hair at the end of the lion's tail was represented by the group of stars called *al-hulbah* (coarse hair) in the *anwāʾ* tradition, which corresponded to the Ptolemaic asterism of Coma Berenices translated into Arabic as *al-ḍafīrah*, meaning a lock of human hair. There appears to have been some confusion in the names applied to Coma and those of the fourteenth and fifteenth lunar mansions.

Al-Bīrūnī (*Chron.* [trns.], 347) briefly gives all three derivations, adding that *al-ghafr* was considered the best of the lunar mansions because it stands behind the lion and before the scorpion. "The evil of the lion lies in his teeth and claws, the evil of the scorpion lies in its venom and the sting of its tail." He says it was commonly asserted that the horoscopes of all the prophets lay in this mansion—a point that he disputes. He gives the position of the fifteenth mansion as 0°0′0″ of the House of Libra, which is the autumnal equinox.

Lunar Mansion 16. *Zubānā*

(Engraved at 205¾° along ecliptic, or 25¾° House of Libra)

Zubānā (the two claws [of the scorpion]) applied to the two large stars, each of which is in one of the pans of the balance of the constellation Libra [$\alpha^{1,2}$ β *Librae*]. This lunar mansion reflects the more ancient Babylonian concept of a scorpion larger than the now familiar Scorpio, of which the constellation now known as Libra formed the claws (Hartner [3], 501; Gundel & Böker, 534–535). Ptolemy in his catalog did not call this constellation a balance but rather the claws (χηλαί) of the scorpion, and so these two were nos. 1 and 2 in his listing for the claws. Not long after Ptolemy, however, the concept of a balance in this area of the heavens was well established and firmly superimposed upon the earlier claws of a large scorpion. In the Arabic tradition the older Bedouin names reflect this ancient image of a large scorpion. See Hommel (597) and Gundel and Böker for a discusion of the origin and meaning of the word *zubānā*. Al-Ṣūfī (*Ṣuwar*, 202) adds that the two stars were called also *yadā al-ʿaqrab* "the two hands of the

scorpion" and *qarnā al-ᶜaqrab* "the two horns of the scorpion." The position given by al-Bīrūnī for the mansion is 12°51′26″ of the House of Libra, or 192°51′26″ from the vernal equinox.

Lunar Mansion 17. *Iklīl*

(Engraved at 218¾° of ecliptic or 8¾° House of Scorpio)

The tradition is not consistent with regard to this lunar mansion, which is called *al-iklīl* (the crown). Al-Ṣūfī (*Ṣuwar*, 202–204) in his discussion of the constellation Libra (see Figures 69 and 70) says that opinions differ among the Arabs with regard to the seventeenth lunar mansion, and presented five different interpretations of *iklīl*.

(1) Three stars across the bar supporting the scales of Libra; the one at the southern end of the bar was not observed by Ptolemy and is not indicated on the Smithsonian globe. These three stars are no. 8 of the formed stars of Libra at the north end of the bar [*θ Librae*]; no. 6 of the unformed stars of Libra above the bar [*κ Librae*, or according to Peters & Knobel it is O^h Arg. 14782, while the fifth unformed is *κ Librae*], and the one not observed by Ptolemy at the southern tip. On globes Nos. 4 and 5 the word *al-iklīl* is engraved at the head of the scales, indicating that this interpretation was in the mind of the makers.

(2) Three stars in a row in the constellation of Scorpio, nos. 1–3 of the formed stars. These are no. 1 in the middle of the three contiguous stars on the forehead of Scorpio, no. 3 in the southern claw, and the star in between, which is no. 2 [*βδπ Scorpii*, respectively]. Al-Ṣūfī rejected this interpretation and asserted that *iklīl* must be one of the other four interpretations that are above the head of Scorpio. Al-Bīrūnī (*Chron.* [trns.], 348) objected to al-Ṣūfī's position and asserted that the common view, not withstanding al-Ṣūfī, was that *iklīl* was composed of these three stars in a straight line.

(3) Three stars, one of which is no. 8 formed of Libra [*θ Librae*] at the northern end of the bar supporting the scales; the other two are no. 6 unformed of Libra [*κ Librae*?] above the bar, and no. 8 unformed of Libra which is the northern of the two on either side of the southern claw of Scorpio [Flam. 39].

(4) Five stars which include the three of the previous interpretation along with no. 9 of the unformed stars of Libra, which is the southern of the two stars on either side of the southern claw of Scorpio [Flam. 40] and a star of sixth magnitude not mentioned by Ptolemy near the no. 6 unformed of Libra near the center of the bar supporting the scales.

(5) Five stars, which consist of the star at the northern end of the bar of Libra [no. 8 formed; *θ Librae*] the star above the bar and to the south [no. 6 unformed; *κ* Librae ?], and three stars not seen by Ptolemy, all of which are above the three in the forehead of Scorpio and which were given as the second interpretation of *iklīl*.

Al-Bīrūnī gives the position of the seventeenth lunar mansion along the ecliptic as 25°42′52″ House of Libra, or 205°42′52″ from the vernal equinox.

Lunar Mansion 18. *Qalb*

(Engraved at 231½° of ecliptic, or 21½° House of Scorpio

Qalb (heart) or *qalb al-ᶜaqrab* (heart of the scorpion) was the given to the eighth star in Scorpio, second from the end of the body (see Figure 70), which is the sixteenth brightest star in the heavens (*α Scorpionis*). The notion of the "heart of the scorpion" arises from the *anwāᵓ* tradition and not from the Greek tradition of Scorpio, in which this star was called Antares, meaning "similar to Mars" since its color, red, resembled that of the planet Mars (see Gundel & Böker, colums 509–522). The position given by al-Bīrūnī is 8°34′18″ of the House of Scorpio, or 218°34′18″ from the vernal equinox.

Lunar Mansion 19. *Shawlah*

(Engraved at 244° of the ecliptic, or 4° House of Sagittarius)

The title *al-shawlah* (the raised tail) or *shawlat al-ᶜaqrab* (the raised tail of the scorpion) was

applied to the two stars at the tip of the tail of Scorpio, nos. 20 and 21 [λυ *Scorpionis*]. Al-Ṣūfī (*Ṣuwar*, 209) also gives the name *ibrat al-ᶜaqrab* (the sting of the scorpion) as a common designation of these two stars comprising the nineteenth lunar mansion. Al-Bīrūnī gives it the position of 21°25′14″ of the House of Scorpio or 231°25′14″ from the vernal equinox.

Lunar Mansion 20. *Naᶜāʾim*

(Engraved at 257° of the ecliptic, or 17° House of Sagittarius)

The title *al-naᶜāʾim* (the ostriches) was applied to a group of eight stars identified by al-Ṣūfī (*Ṣuwar*, 219–220) as being in the Ptolemaic constellation of Sagittarius. The Milky Way passes through this constellation across the figure's bow and arm. In the Bedouin tradition the Milky Way (*majarrah*) was viewed as a river with one group of four ostriches going toward the river and another group of four leaving the river on the other side. The arriving ostriches (*al-naᶜāʾim al-wārid* or *al-naᶜām al-wārid*) were nos. 1, 2, 3, and 25 of Sagittarius: the one of the arrowhead, the one in the hand holding the arrow, the one at the southern tip of the bow and the one in the hoof of the raised front leg [γδεη *Sagittarii*]. The departing ostriches (*al-naᶜāʾim al-ṣādir* or *al-naᶜām al-ṣādir*) were nos. 6, 7, 21, and 22 of Sagittarius, consisting of the one in the hand drawing the bow, the one in front of the hand, and the two below [σφτζ *Sagittarii*]. The eight taken together were called the ostriches. Al-Bīrūnī gives the twentieth lunar mansion the position of 4°17′10″ in the House of Sagittarius, or 244°17′10″ from the vernal equinox.

Lunar Mansion 21. *Baldah*

(Engraved at 270°, or the point of the winter solstice)

The area beneath the fluttering band extending behind the head of Sagittarius was called *al-baldah* (the place) and was said to contain no stars (see Figure 71). Al-Ṣūfī (*Ṣuwar*, 220) called it an open space under *al-qilādah* [i.e., ξοπdρυ *Sagittarii*] in which there is no star. Al-Bīrūnī (*Chron.* [trns.], 348; *Astrol.*, 164) does not mention such a view of al-Ṣūfī's, but compares this desert area (*mafāzah*) to the space between two eyebrows. Kunitzsch ([1961], no. 51) identifies the area as that around Flam. 53, $\chi^{1,2}$ $h^{1,2}$ *Sagittarii*, while Hartner ([3] 502) says it is near π *Sagittarii*. Al-Bīrūnī gives this lunar mansion the position of 17°8′35″ House of Sagittarius or 257°8′35″ from the vernal equinox.

Lunar Mansion 22. *Dhābiḥ*

(Engraved at 282¾° of the ecliptic, or 12¾° House of Capricorn)

The full name of the twenty-second lunar mansion is *saᶜd al-dhābiḥ*, the meaning of which is so obscure that it is virtually impossible to translate. The twenty-second lunar mansion is one of ten groups of *saᶜd* stars, each of which, with two exceptions consists of two stars. Four of these *saᶜd* star groups are lunar mansions; between the two stars comprising each group there is a distance of one *dhirāᶜ*, which for al-Ṣūfī is about 2°20′. Of the other six *saᶜd*-stars, four are in the Ptolemaic constellation of Pegasus, one in Capricorn, and one in Aquarius. The *saᶜd* is of such ancient origin that its significance seems to have been lost by the time the *saᶜd* stars were recorded by the lexicographers in the ninth century. Hommell (p. 606, notes 3 and 4) traces *saᶜd* back to a Babylonian word meaning "demon." Occasionally the word has been translated as "lucky star" but rather inappropriately; "omen" might be somewhat better. The Islamic writers themselves, however, always explained only the adjective or noun modifying the word *saᶜd* and then left *saᶜd* unexplained. Such will be the procedure in this discussion.

The lunar mansion *saᶜd al-dhābiḥ* (the *saᶜd* of the sacrificer or butcher refers to stars in the constellation of Capricorn. One star is at the base of the horn closer to Aquarius, no. 1 [$\alpha^{1,2}$ *Capricorni*], while the other is the larger star to the south, no. 3 [β *Capricorni*] (see Figure 72). The small star standing close to no. 1, the second star of the constellation [ν *Capricorni*] is called, ac-

cording to al-Ṣūfī (*Ṣuwar*, 227), *shā*ᵓ, the sheep or goat that he slaughters (see Kunitzsch [1961], no. 257.5). Al-Bīrūnī assigned the twenty-second mansion the position of 0°0′0″ House of Capricorn, or the winter solstice.

Lunar Mansion 23. *Bula*ᶜ

(Engraved at 295¾° along ecliptic, or 25¾° House of Capricorn)

The full name of the lunar mansion, *sa*ᶜ*d bula*ᶜ (*sa*ᶜ*d* [of the] devourer or swallower) refers to two of the three stars in the hand of Aquarius extended over the back of Capricorn: no. 6 [*ν Aquarii* or Flam. 7], which is the star on the lower palm, and no. 8 [*ε Aquarii*] furthest of the other two. The star in between, no. 7 [*μ Aquarii*] is the star that has been swallowed and is on its way from the throat to the stomach. Al-Ṣūfī (*Ṣuwar*, 238) names all three, but al-Bīrūnī follows Ibn Qutaybah in having only two stars actually compose the lunar mansion, with the middle one too obscure to count (Kunitzsch [1961], no. 257.4). Al-Bīrūnī assigned this mansion the position of 12°51′26″ in the House of Capricorn or 282°51′26″ from the vernal equinox.

Lunar Mansion 24. *Su*ᶜ*ūd*

(Engraved at 308° of the ecliptic, or 8° House of Aquarius)

The full name *sa*ᶜ*d al-su*ᶜ*ūd* could be roughly translated as "omen of good fortune" and was applied to two stars on the west shoulder of Aquarius toward Capricorn, nos. 4 and 5 [*βξ Aquarii*], along with a third star in the end of the tail of Capricorn, no. 28 [c¹ *Capricorni*] (see Kunitzsch [1961], no 257.10 who corrects the Hyderabad text of al-Ṣūfī [*Ṣuwar*, 238]). According to al-Bīrūnī (*Chron.* [trns.], 349) the mansion was given this name "because it rises when the cold decreases, when the winter is past and the season of the continuous rains sets in." The position along the ecliptic given by al-Bīrūnī is 25°42′52″ House of Capricorn, or 295°42′52″ from the vernal equinox.

Lunar Mansion 25. *Akhbīyah*

(Engraved at 321¼° of the ecliptic, or 21¼° House of Aquarius)

*Sa*ᶜ*d al-akhbīyah* (*sa*ᶜ*d* of the tents) is composed of four stars in the east hand and wrist of Aquarius, nos. 9–12 [γπζη Aquarii]. They form a triangle with one star in the middle, while some early writers (Kunitzsch [1961], no. 257.1; al-Bīrūnī *Astrol.*, sec. 169) noted that the pattern was that of a duck's foot (*rijl baṭṭah*). It was said that the central star was *sa*ᶜ*d* and the three surrounding ones were his tents, which perhaps gives support to Hommel's contention that the word *sa*ᶜ*d* was originally the personified concept of a demon. *Akhbīyah* is the plural of *khibā*ᵓ meaning a tent made of wool or camel's hair and supported by three poles. The root of the word means "to conceal"; on the basis of this derivation al-Bīrūnī (*Chron.* [trns.], 439) and al-Ṣūfī (*Ṣuwar*, 239) said the group was given this name because when this mansion rises all that has been hidden in the earth comes out into the rain. These four stars form the modern asterism of the "Y" of Aquarius, also called the Water Jar. Al-Bīrūnī gives the twenty-fifth lunar mansion the position of 8°34′18″ House of Aquarius, or 308°34′18″ from the vernal equinox.

Lunar Mansion 26. *Muqaddam*

(Engraved at 334½° of the ecliptic, or 4½° House of Pisces)

Muqaddam (anterior) is part of the term *al-fargh al-muqaddam* (the anterior spout), which refers to a leather bucket envisioned by the Bedouins in the area of the constellation of Pegasus (see Figure 61). The bucket was formed by the four bright stars on the body of Pegasus (one is shared with the head of Andromeda), nos. 1–4, which form the modern asterism of the Square of Pegasus. The two foremost of the stars (no. 4 immediately above the wing [*α Pegasi*] and no. 3 near the join of the wing and lower leg [*β Pegasi*]) were called "the anterior spout [of the bucket]." Occasionally these two were called *al-fargh al-awwal* (the first spout) (al-Ṣūfī, *Ṣuwar*, 122;

Kunitzsch [1961], no. 92a,b). Al-Bīrūnī assigned this mansion the position of 21°25′44″ House of Aquarius, or 321°25′44″ from the vernal equinox.

Lunar Mansion 27. *Muᵓakhkhar*

(Engraved at 347¼° of the ecliptic, or 17¼° House of Pisces)

Muᵓakhkhar is part of the expression *al-fargh al-muᵓakhkhar* meaning "the posterior spout of the bucket." It refers to the posterior two stars of the Square of Pegasus: no. 2, which is on the corner of the back where it is cut off [*γ Pegasi*], and the one shared with the head of Andromeda [*δ Pegasi* or *α Andromedae*] These two were viewed by the Bedouins as the posterior spout of a leather bucket, and were also called *al-fargh al-thānī* (the second spout; see discussion of Lunar Mansion 26). The position of the twenty-seventh mansion given by al-Bīrūnī is 4°17′10″ House of Pisces, or 334°17′10″ from the vernal equinox.

Lunar Mansion 28. *Rishāᵓ*

(Engraved at 360°, or the vernal equinox)

Al-rishāᵓ (the rope) was one of several names for the twenty-eighth lunar mansion. It was applied to the star on the south side of the waist of Andromeda next to the fish of Pisces [no. 12; *β Andromedae*, Mirach] and was designated a rope in order to supply a rope for the leather bucket seen in the area of Pegasus (see Lunar Mansions 26 and 27).

In a different Bedouin tradition this mansion was also called *baṭn al-ḥūt* (the belly of the fish) because in the early Bedouin conception of this region a large fish was seen to lie across what we now view as Andromeda, making this star the belly of the fish. This fish was much larger than the lower one of the two Pisces, which in the Greek tradition was viewed as being next to Andromeda. The name *baṭn al-ḥūt* is written on the Smithsonian globe next to this star in Andromeda. Al-Bīrūnī (*Chron.* [trns.], 350) adds that this star was also called *qalb al-ḥūt* (the heart of the fish) (Kunitzsch [1961], no. 217; cf. 252). He assigned this mansion the position of 17°8′35″ House of Pisces, or 347°8′35″ from the vernal equinox.

The Forty-eight Constellations

Constellation 1. The Lesser Bear [Ursa Minor]

Figure 49

The Lesser Bear, like the Greater Bear, was called both a bear and a wagon in Greek times, the latter probably being the older image. One can easily observe our asterism of the Little Dipper in the seven formed stars comprising the constellation. The Lesser Bear does not appear in Homer. Aratus (lines 30–44) recounts the story of Zeus having as a child been hidden and nurtured by two bears, the other being the Greater Bear, for which he rewarded them by placing them in the heavens. He also says that the constellation is called *κυνόσουρα*, the Cynosura (dog's tail) as well, and that the Phoenicians sailed by the Lesser Bear, while the Greeks steered by the Greater Bear. In the Islamic world the Lesser Bear was also used as a guide in travel.

The notion of a bear for this constellation as also for the Greater Bear, unfortunately requires that a nearly tailless creature have a long, incongruous tail. The depiction of the Lesser Bear on the Smithsonian globe is with an exceedingly long tail, even longer than that of the Greater Bear, giving it a striking resemblance to a binturong, indigenous to India, rather than a bear. The Greek notion of the Lesser Bear was superimposed in the Islamic world over an earlier Arab conception of the region. The title of the constellation in Figure 49, written in front of the bear, reflects the Greek asterism and reads *ṣūrat dubb al-aṣghar* (constellation of the Lesser Bear).

In the Bedouin tradition a bier or corpse-bearing plank with three accompanying mourning daugthers was also seen here, parallel with the image seen in the Greater Bear. This traditional image was called *banāt naᶜsh al-ṣughrà* (the
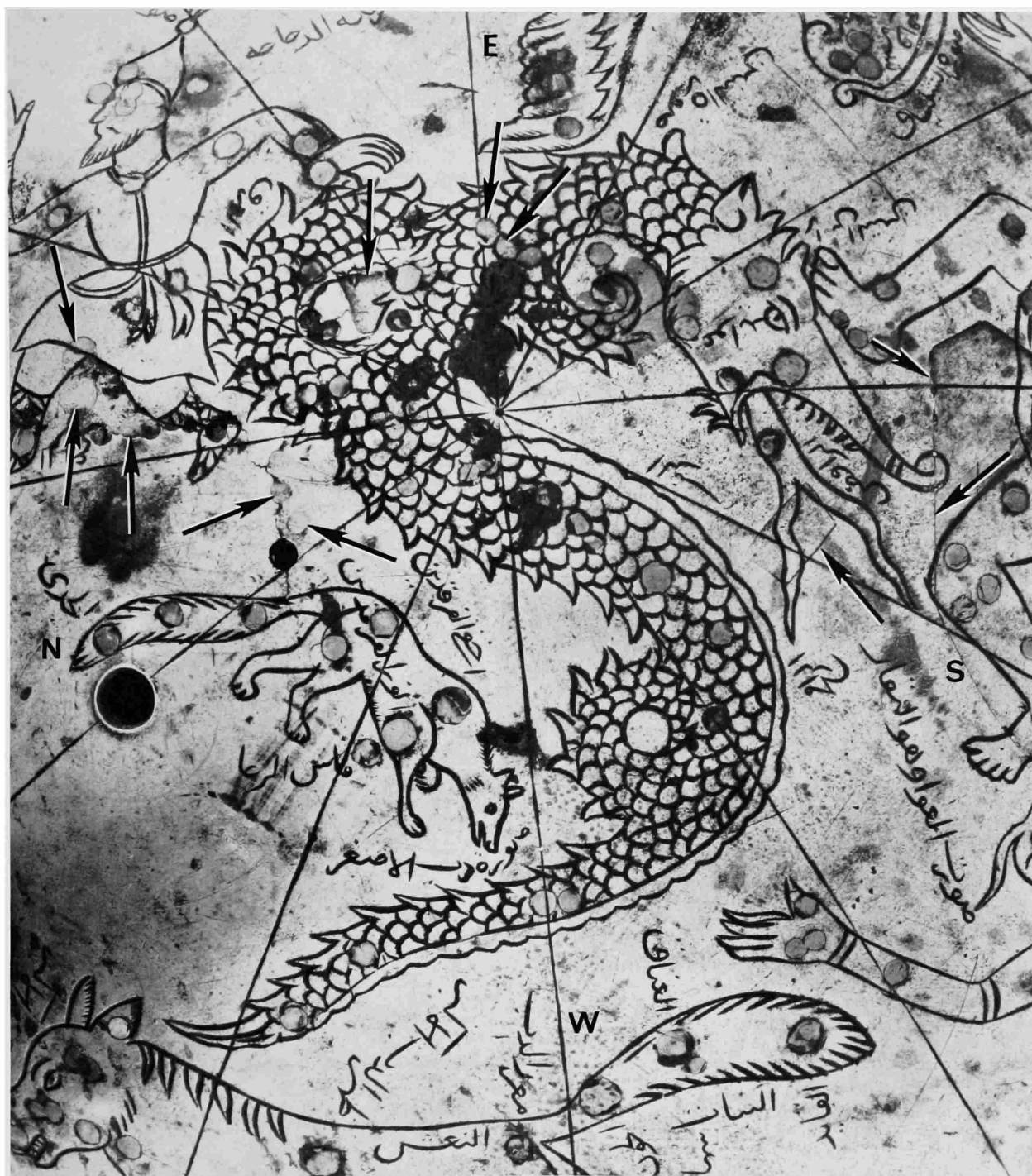
FIGURE 49.—The Lesser Bear [Ursa Minor]. Arrows indicate plugs. (Photo: Smithsonian no. 72-8586)

smaller form of the daughters of the bier), the bier being the four stars in the square [$\beta\gamma\zeta\eta$ Ursa Minoris] and the daughters the three in the tail [$\epsilon\delta\alpha$ *Ursa Minoris*]. This name does not appear on the Smithsonian globe, but does occur on globes No. 4 and No. 5 (see Kunitzsch [1961], no. 96).

Two calves were also seen by the Arabs as belonging to the bier, which al-Ṣūfī identified as the two bright stars of the square, those on the shoulder and front leg [nos. 7 and 6; $\gamma\beta$ *UMi*], respectively. In Figure 49 the star on the shoulder [γ *UMi*] is labeled over the top of the back *akhfà al-farqadayn* (the more obscure of the two calves). The inscription across the middle of the bear applies to the one on the front leg [β *UMi*, Kochab] and reads *anwar al-farqadayn* (the brighter of the two calves). The particular designations of the two stars appear to be unique to the globes made by the Lahore family, though the terms appear in al-Ṣūfī's text and catalog as well as other writings, such as those of Ulugh Bēg.

The star at the end of the tail, the Pole Star [α *UMi*, Polaris], is labeled *al-jadī* (the goat) in Figure 49. This name is also of ancient Arab origin. The large hole drilled next to it is the hole of the celestial (equatorial) North Pole.

The constellation has in addition to seven formed stars, one unformed one beneath the stomach of the Lesser Bear. This star is labeled *faʾs al-raḥā* "the axis of the millstone" [Flam. 5, *UMi*] in Figure 49. Al-Ṣūfī (*Ṣuwar*, 28) said it resembled the axis of a millstone that had in its center the North Pole; some people called the star simply "the axis of pole" (al-Bīrūnī *Astrol.*, sec. 160; Kunitzsch [1961], no. 97c). The word *faʾs* more precisely means the protuberance on the edge of a millstone where the axis or rod was attached to turn it. The Pole was seen as being the center of the millstone turning in a socket, while at the *faʾs* a beam or rod was attached to the millstone that had at the other end of the rod the two calves, *farqadān* [$\beta\gamma$ *UMi*], who turn the grist mill.

It was also said (Ideler, 15–16; Kunitzsch [1961], no. 970) that around the North Pole were obscure stars that together with the "smaller form of the daughters of the bier" formed the shape of a fish in whose middle is the North Pole. Ulugh Bēg states that the small stars around the Pole form *ihlīlaj* (the fruit of the myrobalan), the latter being the name of a tree native to Asia bearing edible red or yellow fruit. These images are not known to be represented on any celestial globes.

Constellation 2. The Greater Bear [Ursa Major]

FIGURE 50

This constellation is the best known of all constellations, for a brilliant part of it forms what is known in our time as the Big Dipper. This latter asterism, however, forms only a part of the area covered by the Greater Bear. Because of the prominence of this area of the heavens, several different images have been superimposed upon the region.

Homer (*Od.*, v,273) speaks of the Bear (ἄρκτος) "which men also call the Wagon (ἄμαξα) which ever circles where it is." Aratus (lines 26–44) uses both names, giving it the additional name Helice (ἑλίκη), which implies convolutions and may refer to its being a circumpolar asterism. Hyginus (II,1) presented the legend that it was a companion of Artemis named Callisto who became pregnant by Zeus and was changed into a bear by Artemis.

The oldest and most persistent image in the Arabic world is that of a bier or corpse-bearing plank, formed by the four bright stars in the bowl of our Dipper, followed by three mourning daughters (the three stars of the tail or Dipper handle). Thus in Figure 50 there is written on the rump of the back *al-naʿsh* (the bier), referring to the four stars forming the square [$\alpha\beta\gamma\delta$ Ursae Majoris]. Under the tail and parallel to it is the word *al-banāt* (the daughters), referring to the three bright stars of the tail [$\eta\zeta\epsilon$ *UMa*].

Since the Greek image of the Bear is superimposed over the Bedouin bier, the constellation is titled *ṣūrat dubb al-akbar* (the form of the Larger Bear) written along the head. The long

FIGURE 50.—The Greater Bear [Ursa Major]. (Photo: Smithsonian no. 72-3098)

tail on the bear on the Smithsonian globe, as well as its mane, gives it an unbearlike appearance. There are, however, other globes (e.g., No. 1) where the bear is shown with a very short, stumpy tail. The individual names of the four stars forming the square in Figure 50 reflect the Ptolemaic image of the bear. Thus the one in the middle of the back is labeled *ẓahr al-dubb al-akbar* (the back of the Greater Bear [no. 16; α *UMa*, Dubhe]); at the base of the tail the star is named *maghriz al-dubb* (base of the bear [no. 18; δ *UMa*, Megrez]); the one immediately below is called *fakhdh al-dubb* (thigh of the bear [no. 19; γ *UMa*, Phecda]); and the star in the stomach is called *mirāt al-dubb* (loin of the bear [no. 17; β *UMa*, Merak]).

The names of the stars in the tail arise from the Bedouin tradition. The first star of the tail, no. 25, is called *al-jawn*, the black horse (ε UMa, Alioth; see Kunitzsch [1961], no. 106). The large star in the middle of the tail is called *al-ᶜanāq* (the goat [no. 26; ζ *UMa*, Mizar]) and the last star of the tail [no. 27; η *UMa*, Alkaid] is *al-qāᵓid* (the leader), possibly being viewed as the leader of the funeral train. The small star next to the middle of the tail [g *UMa*, Alcor] was not listed by Ptolemy. Consequently al-Ṣūfī (*Ṣuwar*, 32) named it *al-suhā* (the overlooked one), a name it bears in Figure 50. Al-Ṣūfī added that this is a star by which men test their vision, but did not assign it a place in his catalog.

Another Bedouin image is reflected in the designation of the twin stars in each of the three prominently depicted feet of the Bear. These stars are labeled, beginning with the rear paw, *al-qafzah al-ūlà* (the first leap) *al-qafzah al-thāniyah* (the second leap) and *al-qafzah al-thālithah* (the third leap) [nos. 23, 24, 20, 21, 12, 13; νξλμικ *UMa*, respectively], and refer to the image of a deer or gazelle running before a lion. Each pair of stars was so named because they resembled the track of a deer's cloven hoof. In Figure 50 the lower front paw bears the label *tatimmat qafzah al-thālithah* (complement of the third leap), which apparently refers also to ικ *UMa*. This name occurs on only two other globes, Nos. 11 and 13, and is unknown in astonomical literature. The maker wrote the name "the third leap" in front of the front legs, perhaps intending for it to refer to the two stars above those in the lower front paw. The maker of the globe may not have understood the image of the deer, for the term for "leap" is actually incised as *al-faqrah* "vetebra" (a difference of two diacritical points over the word). An identical spelling occurs on globes No. 11 and No. 13.

The constellation is composed of 27 formed stars, to which this maker adds the additional "overlooked star." There are eight unformed stars, five grouped beneath the bear, with one isolated in front of the front paw and two beneath the tail. The image of the large lion chasing the deer is reflected in the name of one of the two unformed stars beneath the tail, which is labeled *kabid al-asad* (liver of the lion [no. 1 unformed; α *Canum Venaticorum*; see Kunitzsch [1961] 135).

Constellation 3. The Dragon [Draco]

FIGURE 51

Draco was not one of the star groups mentioned by Homer. Aratus (lines 45–62) says the dragon winds between the two bears like a branch of a river. Its head is under the foot of the Kneeler (Hercules) and it coils about the pole of the ecliptic, to which the great circles dividing the ecliptic into 12 houses can be seen converging. Several dragons of Greek legend were associated with the figure: (1) the dragon that guarded the Garden of the Hesperides, thus associating it with Hercules, whose form is to be seen above the dragon's head; (2) the dragon killed by Cadmus; and (3) the Python killed by Apollo.

With the introduction of Ptolemaic astronomy into the Islamic world, the concept of the dragon was quite literally transferred into this region, overlaying the earlier Bedouin tradition. The constellation is called *ṣūrat al-tinnīn* (the constellation of the dragon) written in Figure 51 above its neck (see also Figure 49 for details). The large star behind the eye is labeled *raᵓs al-tinnīn* (head of the dragon [no. 5; γ *Draconis*]).
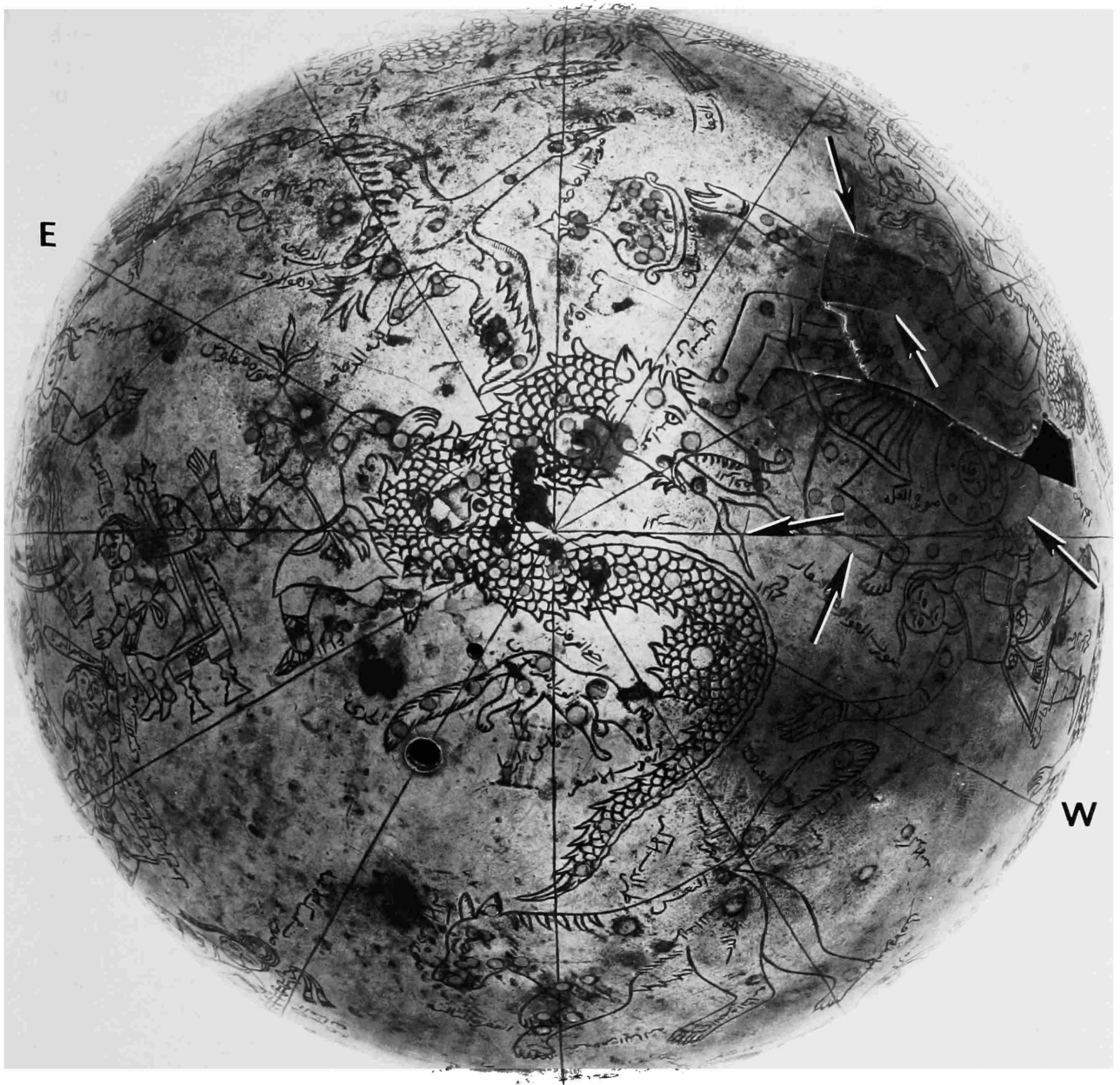
FIGURE 51.—The Dragon [Draco]. This view shows the entire area around the northern ecliptic pole. (Photo: Smithsonian no. 72-3082)

The remaining stars named in Draco reflect the early Bedouin tradition of camels, wolves, and hyenas. Thus, the four stars forming a square on the head (nos. 5, 4, 3, 2) are labeled *ᶜawāʾidh* (the camel-mothers [$\gamma \xi \beta \nu$ *Dra*; Kunitzsch (1961), no. 42]). The star on the tongue [no. 1; μ *Dra*] is labeled *al-rāfiḍ* (the wandering [camel]). This is probably a mistake, a matter of the distribution of the diacritical points, for *al-rāqiṣ* (the ambling [camel]) as it reads in the text of al-Ṣūfī (*Ṣuwar*, 41; see Kun., 240). However al-Qazwīnī (Ideler, 32) and globe No. 4 also read *rāfiḍ*. Written

along the second turn of the dragon, along the back of the spine under the chin, is the word *al-dhīb* (the wolf). This probably refers to the large star south of the word [no. 25; *η Dra*]. Al-Ṣūfī and others (Kunitzsch [1961], no. 79) also spoke of two wolves, the other being the third star to the north of the latter [no. 24; *ζ Dra*]. Along the spine of the back at the tip of the tongue there reads *al-dhīkh* (the manlike hyena), which refers to the second star to the south of the wolf [no. 27; *ι Dra*; see Kunitzsch [1961], no. 80].

According to Ptolemy the dragon consisted of 31 internal stars. The Smithsonian globe also shows 31 stars in this constellation. Although some are actually external to the form of the dragon, this was probably an error on the part of the artisan. On the neck of Draco before the first coil are two plugs, which appear in Figures 49 and 51 to be stars, but are not. They are indicated by arrows. Al-Ṣūfī recorded another star, without a number, which had not been observed by Ptolemy. This star was in the midst of the four "camel-mothers" near the eye and was called *al-rubaᶜ* (the young camel). Only one globe, No. 3, is known to have this particular label.

Constellation 4. Cepheus

FIGURE 52

In the Greek world Cepheus was the name of four or five mythological figures, of which perhaps the best known was the king of Ethiopia and the husband of Cassiopeia, whom he faces as a constellation. Aratus (lines 179–188) says he is located in the area near Cynosura, the Lesser Bear, which is below his feet. Hipparchus (*Comm. arat.*, I, 2.11), however, criticizes Aratus for having the size of the constellation too large. In classical descriptions of the constellations, Cepheus was the only bearded person, indicating that he was a foreign king. On the Smithsonian globe, however, there are three other bearded forms: Perseus, Aquarius, and the Centaur, as well as the ogre's head carried by Perseus. Both al-Bīrūnī (*Astrol.*, sec. 160) and al-Ṣūfī (*Ṣuwar*, 49) refer to Cepheus wearing a conical hat (*qalansuwah*).

In Figure 52 the title is written near his exotic headress, *ṣūrat qīqāʾūs* (the constellation of Cepheus), the latter being a transliteration of the Greek κηφεύς (Cepheus).[38] All star names reflect an older indigenous Arabic tradition of a shepherd, his dog, and his flock, rather than the Ptolemaic tradition of a human figure. In Figure 52 the star on his forward foot, the second star of the constellation [*γ Cephei*] is called *al-rāᶜī* (the shepherd). The star on the northern tie of his sash (no. 3) is *β Cephei*, whose modern name Alfirk is derived from a name applied by the Bedouins not just to this star but also the one above on his upper arm, the fourth of the constellation [*α Cephei*]. *Kawkabā al-firq*, as al-Ṣūfī (*Ṣuwar*, 46) called these two, means "the two stars of the flock" referring to the flock tended by the shepherd [*αβ Cephei*]. The word *al-firq* (the flock) is engraved on the Smithsonian globe under the arm of Cepheus near Draco.

In keeping with the image of a shepherd and his flock al-Ṣūfī (*Ṣuwar*, 47) recorded a star between the two legs, which had not been observed by Ptolemy and to which he consequently did not assign a number. This star he called *kalb al-rāᶜī* (the shepherd's dog [Flam. 28, 29 *Cephei*]). It does not appear on the Smithsonian globe, since only one of the unnumbered stars of al-Ṣūfī is indicated (the "overlooked star" in Ursa Major). On some globes (e.g., Nos. 4 and 5) *Kalb al-rāᶜī* is written between the legs but with no star inlaid there, so that it was interpreted as applying to the star on the back foot [*κ Cephei*].

In addition to "the shepherd's dog" al-Ṣūfī recorded four external stars near the elbow of the back arm and four stars on the forward leg, which had also not been observed by Ptolemy. These nine stars, however, he did not number. Thus his catalog has 11 formed stars and 2 unformed stars, on either side of the head, as did Ptolemy's. Figure 52 also has 11 formed and 2 unformed stars. Two medium sized plugs can be seen on and near the southern leg, as well as a row of small plugs between the feet (indicated by arrows). What appears to be a star on the front (southern) tie of his sash is actually a plug and not a star. The star on Cepheus's back (northern)

FIGURE 52.—Cepheus. (Photo: Smithsonian no. 72-3099)

foot was put in but has now fallen out. The other circles of the same size are in reality plugs.

Constellation 5. The Howler, that is, the Ox-Driver [Boötes]

FIGURE 53

The name "ox-driver" given by the maker of the Smithsonian globe as the second name of the constellation (*al-baqqār*) is a translation of the Greek name βοώτης (ploughman), which appears in Greek literature as early as Homer (*Od.*, V, 272) where it apparently applies not to the entire constellation, but to its brightest stars. In the *Odyssey* the name of ploughman given this asterism is in keeping with the name of wagon, given to the Greater Bear. Thus Boötes is the ploughman or driver of the wagon represented by part of the Greater Bear. Aratus (lines 91–95, [trns.], Mair, 215) calls the constellation ἀρκτοφύλαξ (guardian of the bear) "whom people also call Boötes since he seems to lay hand on the wain-like Bear." Beneath his belt is the bright star ἀρκτουρος (guard of the bear). From the latter name we derive the star's common name today Arcturus, the fourth brightest star of the heavens. The Smithsonian globe is unique among studied globes in that it indicates a knowledge of the correct Greek name of the constellation.

The first title, *ṣūrat al-ᶜawwāᵓ* (the form of the Howler), is the usual Arab designation, and is derived from a misunderstanding of the word βοώτης (the ploughman) as reading βοητής (the howler or shouter). It may be that the figure was viewed as a herdsman driving the Great Bear before him. Indeed in nearly all instances he is depicted as following Ursa Major, except on globe No. 4, where he is facing away with his head turned back toward the bear. The second part of the title "that is to say, the ox-driver (*al-baqqār*)" reflects a closer rendering of the Greek βοώτης (see Kunitzsch [1974], 174–176, for other names such as *ḥāris al-shamāl*, "the guardian of the north").

The constellation consists of 22 internal stars, one of which it shares with Hercules (the one at the tip of the sword). Immediately above the hilt of the sword there are actually two small inlaid stars next to one another; on the globe they appear almost as one). There is one unformed star below the hemline of the tunic. In Figure 53 can be seen a damaged area of the globe. A small area is missing and a crack occurs above it; immediately to the left can be detected one of the two large plugs in the globe. There is also faintly visible on Boötes's western chest and thigh toward the south a smaller, nearly rectangular plug. Only two stars of this constellation are named on the Smithsonian globe. Both star names seem to reflect the Bedouin image of a lancer, or at least an armed form, rather than a "howler" or an ox-driver derived from Greek tradition. On the forward leg the largest of the three stars is named *mufrad al-rāmiḥ* (the solitary [star] of the lancer). *Mufrad* (the solitary) may have been seen originally as outside the lines of the armed figure. This star (no. 20; *η Boötis, Mufrid*) appears labeled only on globes made by the Lahore family, and the globe made by ᶜAlī Kashmīrī (No. 10). The star is given this title in the illustrations to Ulugh Bēg's copy of al-Ṣūfī (see al-Ṣūfi *Ṣuwar*, figure 5) but al-Ṣūfī himself calls it *rumḥ* (the lance), as do most other writers (Kunitzsch [1961], no. 255).

The second labeled star in Boötes is the very large one beneath the hem of the tunic, the first unformed star of the constellation. This is *α Boötis* or Arcturus. The precise meaning of the Arabic name for this star, *simāk al-rāmiḥ*, is difficult to determine. The word *simāk* occurs for a star in Virgo, which gave its name to the fourteenth lunar mansion. The word *simāk* is perhaps of Babylonian origin, but its meaning is so obscure that it cannot be translated. The word *al-rāmiḥ* usually acts as an adjective meaning "armed" or "fighting," and so we have a lance-bearing or fighting *simāk*. On the Smithsonian globe the word *al-rāmiḥ* does not actually function as an adjective, but this is probably another grammatical error of the maker (see Kunitzsch [1961], no. 270; on globes Nos. 1, 3, and 34 the word *simāk* does not appear, only *al-rāmiḥ*). The star Arcturus was also by some (Kunitzsch [1961], no. 77) given the name *al-dhakar* "the

FIGURE 53.—The Howler, that is, the Ox-Driver [Boötes] and the Crown [Corona Borealis]. (Photo: Smithsonian no. 72-3090)

penis." This may not be a true Arab name, however, but only a designation arising after the introduction of the Ptolemaic constellation. For the star stands in Boötes *baina fakhidhayhi* (between his two thighs), as al-Ṣūfī says (*Ṣuwar*, 52) from which the term *al-dhakar* could easily have arisen. It seems that in the Bedouin tradition the two *simāks* (in Virgo and Boötes) were viewed as the two hind legs of the large lion.

Constellation 6. The Crown [Corona Borealis]

FIGURE 54

To the west of Draco, between the two figures of Hercules and Boötes near the damaged section of the Smithsonian globe, are two concentric circles representing the constellation of the Northern Crown (see Figure 54 for detailed view). Aratus (lines 70–71, [trns.], Mair, 213) called it στέφανος, a wreath or garland "which glorious Dionysus set to be a memorial of the dead Ariadne." On the two earliest globes (Nos. 1 and 34) the Greek title is literally translated as *al-iklīl al-shamālī* (the northern wreath), and so it is found in al-Ṣūfī where it is drawn as two concentric circles. Al-Bīrūnī (*Astrol.*, sec. 106) says it is generally known as "the dish of the orphans and poor people" (*qaṣʿat al-yatāmā wa al-masākīn*).

The etymology of the more common Arabic name *al-fakkah*, engraved on the Smithsonian globe above the outer ring, is puzzling. The basic root of the word means "to break" or "to release." There is a break or gap between the two northernmost stars [πι *Coronae Borealis*] of the ring of eight stars making up the constellation. The word *al-fakkah* may refer to this break (Kunitzsch [1961], no. 85). At this gap the knot of the wreath is tied, when it is pictured as a garland. The gap could also represent a break in a dish or plate, which might account for al-Bīrūnī's term "the dish of orphans and poor people."

On globes No. 26 and No. 1 it is drawn as an open horseshoe but on all others it is a closed plate or ring, except the early eighteenth-century globe, No. 31, where it is actually a crown. The largest and brightest star of the constellation [α *CrB*, Alphecca], the fourth star counting from the southern side of the gap, is labeled, within the inner ring, *nayīr fakkah*. This is poor grammar for *al-nayīr min al-fakkah* (the brilliant star of *al-fakkah*). Al-Ṣūfī (*Ṣuwar*, 57) also calls it *al-munīr min al-fakkah*.

Constellation 7. The Kneeling Man [Hercules]

FIGURE 54

The position of Hercules is up-side-down, kneeling on his rearmost (western) knee, with his foot stepping on the head of Draco; he is head to head with the serpent bearer, Serpentarius. In the Arabic tradition he is usually called simply *al-jāthī* (the kneeling man) from the form of the Greek constellation, although al-Ṣūfī adds that he was also called *al-rāqiṣ* (the dancer; Ideler, 381). On the Smithsonian globe the figure is drawn so that the raised hand appears to be a right rather than a left hand, and both his feet are shown with the large toe on the same side of the foot. In Figure 54 a large plug in the globe can be seen to extend across the back (western) leg of Hercules. A fairly large rectilinear plug is over his eastern shoulder and a small rectangular plug can be seen on his eastern thigh.

When Aratus wrote his poem in the third century BC the attribution of Hercules to the constellation had not been made. Aratus (lines 64–66; [trns.] Mair, 213) says "that sign no man knows how to read clearly, nor on what task he is bent, but men simply call him On His Knees." The Greek reads ἐγγόνασις, i.e., ὁ ἐν γόνασι καθήμενας. Aratus (lines 270; 64; 73) also several times calls him "the unknown phantom" or simply "phantom" (εἴδωλον). Gradually, however, the mythological figure of Hercules, or Heracles (ἡρακλῆς) as he was called in the Greek world, came to be attached to the form of a kneeling, toiling man. Hyginus and later mythographers identified him with Theseus, Ixion, Prometheus, Orpheus, and others. It is interesting, however, that Ptolemy calls the constellation only "he who is on his knees" and never Hercules. The kneel-
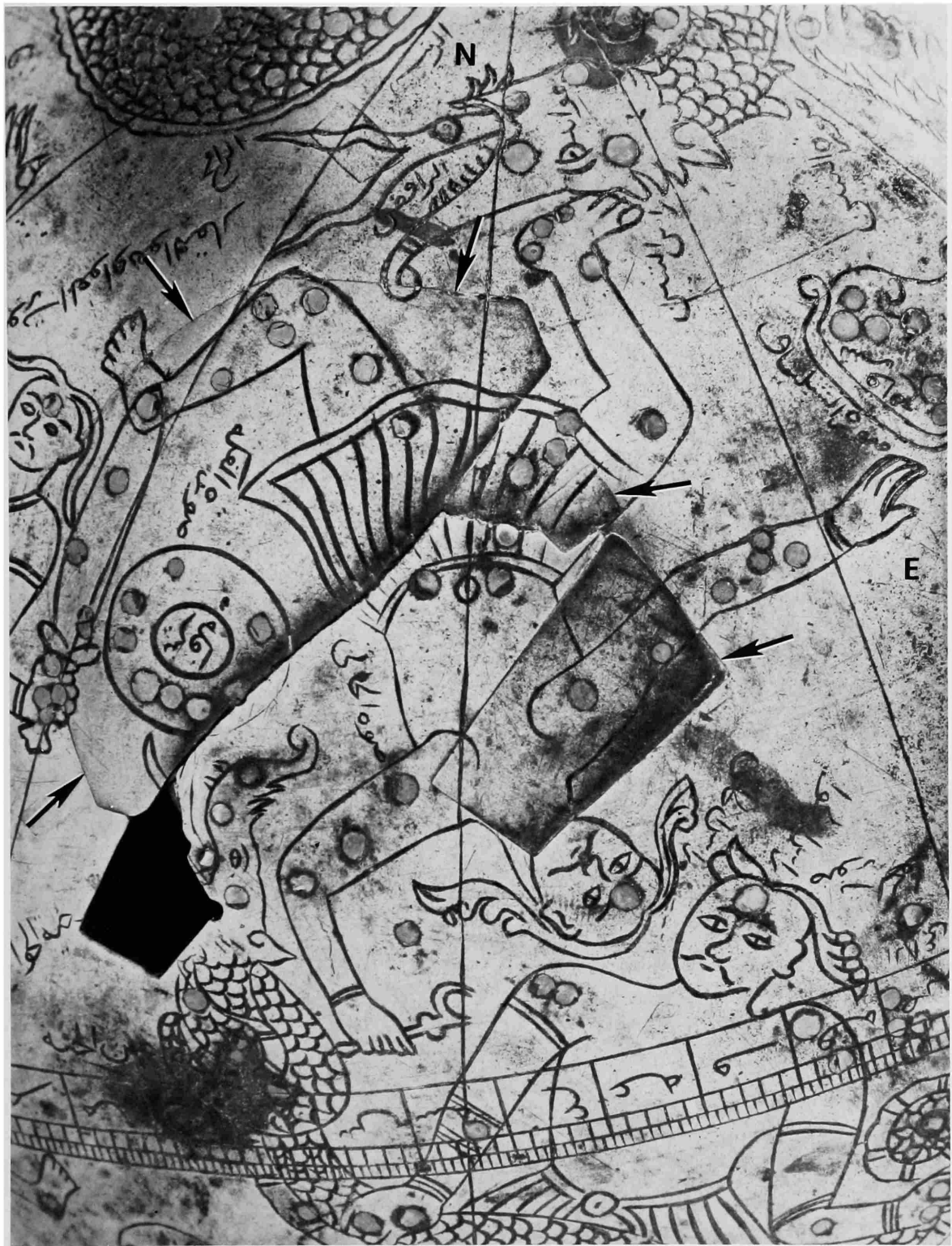
FIGURE 54.—The Kneeling Man [Hercules] and the Crown [Corona Borealis]. Arrows indicate plugs. (Photo: Smithsonian no. 72-3094)

ing figure has his forward foot on the head of Draco, so that he could be interpreted as Hercules fighting the dragon that guarded the Garden of the Hesperides, the twelfth labor assigned to Hercules. The attribution of Hercules to the constellation works in nicely with the interpretation of some of the other nearby constellations. For instance Hydra, the sea serpent, could be interpreted as the Lernean Hydra of his second labor. A centaur also plays a role in the story of Hercules, and Sagitta the arrow could be thrown by Hercules toward Aquila (the eagle), Lyra, and Cygnus, distorted representations of the Stymphalian birds of his fifth labor.

The figure was frequently depicted with a lion's skin over his forward arm and a shepherd's crook in the back raised hand. In the Islamic world the lion's skin is not shown, and in place of the shepherd's crook is the oriental scimitar. Wellesz ([1959], 5), suggested that this scimitar was an early misunderstanding of the shepherd's crook on the part of the illustrator of al-Ṣūfī's treatise. On the earliest globe (No. 1) there is no weapon in the hand of the Kneeler, but on all other globes there is a small scimitar-like weapon in the raised back hand.

The Arabic title for the constellation, *ṣūrat al-jāthī* (the constellation of the kneeling man), literally translates the older Greek title. It is written along the figure's western side between Corona Borealis and Hercules. The constellation is composed of 29 formed stars and one unformed star above the raised upper shoulder. Al-Ṣūfī numbers them 1 unformed, 28 formed, and 1 unnumbered formed star on the back foot, which it shares with Boötes.

The only star labeled on this globe is the one in the head, which is called *raʾs al-jāthī* (the head of the kneeling man [*α Herculis*]). While this designation for the first star of the constellation is given by al-Ṣūfī, he also gives the Bedouin term *kalb al-rāʿī* (the shepherd's dog). (See the discussion of Serpentarius for the shepherd and another one of his dogs.) The term "the shepherd's dog" is found on globe No. 4 for this star. On the earliest globes (Nos. 1 and 34) as well as No. 5, *α Herculis* is not labeled. On globe No. 3 the star is called simply *raʾs* (head). But on the globes of the Lahore family as well as the Smithsonian globe, and the later globe No. 31, it is labeled "the head of the kneeling man," reflecting the Greek rather than the Bedouin asterism. The Smithsonian globe does not label a prominent row of stars across his two arms [nos. 4, 3, 2, 5, 6, 7, 8, 9 and 10 of Hercules; *κγβδλμονξ Herculis*], two stars of the constellation Lyra at the end of his forward hand [nos. 7 and 9; *βγ Lyrae*], and two from the Serpent near his back raised elbow [nos. 4 and 3; *βγ Serpentis*]. These stars are called by al-Ṣūfī *al-nasaq al-shaʾāmī* (the northern row), a name which they bear on all globes except the two earliest (Nos. 1 and 34) and the Mughal ones. This row of stars was thought to be the northern boundary of a meadow, the southern boundary being formed by a row of stars in Serpentarius (Kunitzsch [1961], nos. 243, 192a).

Constellation 8. The Lyre [Lyra]

FIGURE 55

The Arabic title of this constellation, *ṣūrat al-shulyāq*, may be derived from the Greek word χέλυς, meaning tortoise. Since the lyre was made by stretching seven strings on a tortoise shell which then acted as a sounding board, χέλυς came to mean lyre. Aratus (lines 268–274) speaks of the tortoise, which Hermes pierced for strings and named the lyre (λύρα), and was placed by Aratus as a constellation between the Bird (Cygnus) and the forward knee of Kneeling Man. Al-Ṣūfī (*Ṣuwar*, 67) says it is the constellation *al-lūrā*, a transliteration of the Greek **lýra** and adds that it is also called *al-shulyāq*, *al-ṣanj* (a Persian word for cymbals or brass castanets), *al-miʿzaf* (a triangular harp with seven strings equivalent to the Greek *κιθάρα*), *al-iwāzz* (a goose), and *al-sulaḥfāt* (a tortoise). The latter word appears on the two oldest globes, Nos. 1 and 34. Indeed on No. 1, the form engraved is that of a tortoise. The exact origin of the word *shulyāq* as used on the Smithsonian globe seems uncertain (see al-Ṣūfī [trns.], 75 note 2); it is possible it arose as a

FIGURE 55.—The Lyre [Lyra] and the Fowl [Cygnus]. (Smithsonian no. 72-3092)

misunderstanding and incorrect writing of *sulaḥfāt*. In any case it appears that the meaning of the word as a musical instrument was soon lost, for on globe No. 3 it is merely a decorative device, while Nos. 4 and 5 show the constellation more as a cup or jug. Some illustrations of al-Ṣūfī manuscripts depict it as an urn (Wellesz [1959], figure 22b; Upton, 143), while others show it as a tortoise (al-Ṣūfī *Ṣuwar*, figure 8). On the Smithsonian globe and No. 26 (also by the Lahore family) it is drawn to resemble a crown. The constellation is composed of 10 formed stars. Al-Ṣūfī (*Ṣuwar*, 68) notes an extra star which he had seen on globes. In light of this it is interesting that the eleventh century globe, No. 34, has 11 stars on it.

Only one star is labeled on the Smithsonian globe, Vega [α *Lyrae*], the fifth brightest star of the heavens. It is the lower (westernmost) star, at the vertex of the triangle of stars on the northern side, indicated by a slightly larger silver dot. It is labeled *nasr wāqiᶜ* (a falling eagle), the Vega being a corrupt transliteration of *wāqiᶜ* (falling). Al-Ṣūfī (*Ṣuwar*, 68) and al-Bīrūnī (*Astrol.*, sec. 163) apply the name only to α *Lyrae*, while the three stars of the triangle together (nos. 1–3) are called *al-athāfī* (the legs of a tripod). Others (Kunitzsch [1961], no. 195a) interpreted "the falling eagle" as referring to the three stars $\alpha\epsilon^{1,2}\zeta^{1,2}Lyr$, suggesting the form of a bird with half-closed wings and hence falling and in peril (see Figure 23, globe No. 46, which depicts it as a falling bird).

Constellation 9. The Fowl [Cygnus]

FIGURE 55

In Greek literature this constellation was conceived of as a flying bird, usually a swan. Aratus (lines 275–281) used the word ὄρνις, a general word for bird, both a wild bird of prey and a domestic fowl, saying it is a bird ἠερόεις (wreathed in mist; i.e., in the Milky Way), whose western wing tip stretches out toward Cepheus, whose hand we see near Draco, while its other wing is near the prancing horse (Pegasus). Later writers (e.g., Erat. *Catast.*, 25) refer to it as the κύκνος (the swan), and traditions associate it with the story of Leda and the swan. In the Arabic world the word *al-dajājah* is used, which can mean any type of fowl, but in particular domestic fowls, hens and cocks. Al-Ṣūfī also uses the even more general word for bird, *ṭāʾir*, but this does not occur on globes. Al-Bīrūnī (*Astrol.*, sec. 160) adds that *al-dajājah* is like a duck (*baṭṭah*) with its neck and wings stretched out as if it were flying. On all globes studied prior to those of Mughal India, the bird is clearly a type of barnyard fowl with a wattle or comb and with wings partially closed so that it appears not to be flying. On the Smithsonian globe, however, the bird, whose title is written below its head, has its wings fully outstretched as in flight, the neck and head are straight, and there is no sign of a wattle or comb, giving it the general appearance of a goose or swan.

The constellation consists of 17 formed stars and 2 unformed ones. The very large star at the base of the tail is labeled *dhanab al-dajājah wa huwa al-ridf* (the tail of the fowl, that is to say, the follower). This star is no. 5, α *Cygni*, named today Deneb, obviously derived from *dhanab*, meaning tail. The word *al-ridf* (the follower) arose from the Bedouin concept of four stars across the upper edge of the wings [nos. 6, 4, 10, 12; $\delta\gamma\epsilon\zeta$ *Cyg*] as Horsemen (labeled *al-fawāris* on globes Nos. 4 and 5; see Kunitzsch [1961], no. 98). The star α *Cyg* was then "the follower" or "the one riding behind" the horsemen. The label on the Smithsonian globe gives both the Ptolemaic and Bedouin star names, while on some of the other later globes, such as Nos. 26 and 31, only the Ptolemaic "tail of the fowl" is given.

In Figure 55 the star in the bill of the bird is called *minqār al-dajājah* (the bird's beak [no. 1; β *Cyg*]) and the star in the bend of the northern leg is labeled *rukbat al-dajājah* (the bird's knee [no. 17; $\omega^{1,2}$ *Cyg*]. These basically Ptolemaic designations do not seem to occur on Class A globes prior to the Lahore family, but were considered by al-Ṣūfī to be "astrolabe" stars, and hence are

found on some Class B globes. The star in the bill and the one in the tail plus the Horsemen form what today is known as the asterism of the Northern Cross [αβγδεζ *Cyg*].

Constellation 10. The Lady with a Chair [Cassiopeia]

FIGURE 56

Aratus (lines 188–196) identifies this group with κασσιέπεια, the wife of Cepheus, who stands behind her toward the north. He also says the stars (the well-known W-shape) resemble "the key of a twofold door barred within, wherewith men striking shoot back the bolts" ([trns.] Mair, 223). A Greek tradition that developed by the time of Ptolemy drew her as a queen sitting on a throne with her arm outstretched toward her daughter Andromeda, whose foot can be seen above her open hand. The legend goes that Cassiopeia boasted she was fairer than the sea nymphs, the Nereides, for which brashness Poseidon sent a flood and a sea monster (Cetus, another constellation to be discussed in Figure 75) to ravage the coast of her realm in Ethiopia (Hyginus, II, 10). The only way in which Cepheus and Cassiopeia could rid their realm of the sea monster was to sacrifice their daughter Andromeda to the monster. Their subjects thus compelled them to chain her to a rock to be devoured. She was later rescued by Perseus, who can be seen as a constellation south of Cassiopeia's legs (see Figure 57). Cassiopeia, however, was banished by Poseidon to the sky, but so near the Pole Star that she hangs downward half the year as a lesson in humility.

In the Arabic world her name was not transliterated into Arabic, but was lost completely. She is simply called the lady with the chair (*dhāt al-kursī*), as can be seen in the title written above her head in Figure 56. The constellation consists of 13 formed stars. Near her forward leg is written *rukbat dhāt al-kursī* (the knee of the seated lady). This does not occur on any other globe studied, but it is to be found in Ulugh Bēg's copy of al-Ṣūfī's treatise (*Ṣuwar*, figure 10; see also Wellesz [1959], figure 68), where it clearly refers to the large star in her lap [δ *Cassiopeiae*], the fifth of the constellation. It is no doubt intended to apply to that star on the Smithsonian globe as well, and not to one of the two in the leg that were considered of fourth magnitude, and thus seldom given individual names.

The large star on her raised elbow [β *Cas*] is labeled *kaff al-khaḍīb* (the dyed hand), that is, a hand dyed with henna (*ḥinnāʾ*), a red dye made from *Lawsonia inermis*. The star name is more frequently and correctly written as *al-kaff al-khaḍīb* (cf. Wellesz [1959], figures 68, 62, 47; Kunitzsch [1961], no. 136, 136b). On our globe, as on all known globes, it appears to refer only to this one large star on her elbow, no. 12 of the constellation. However, as al-Ṣūfī notes (*Ṣuwar*, 77), names referring to a configuration of stars were sometimes used by astronomers to refer to only one of the stars of the group, as in this case when this became an important star and was put on astrolabes. Accordingly, in the Bedouin tradition *al-kaff al-khaḍīb* (the dyed hand) refers to five white stars in the Milky Way (*majarrah*), which are identified by al-Ṣūfī as referring to the W-shaped asterism, i.e., nos. 12, 2, 4, 5, and 6 of the constellation [βαγδε *Cas*]—one in her elbow, one in her cheek, at her waist, on her lap and the upper of the two on her northern leg. These five stars were viewed by the Bedouins as being the open hand of the upper extended arm (passing through Perseus) of a figure named *al-thurayyā*, whose head was the Pleiades. (See the discussion of Lunar Mansion 3, the Pleiades.) Al-Ṣūfī (*Ṣuwar*, 77) also designated the star on her elbow as *kaff al-khaḍīb wa huwa ʿalà sanām al-nāqah* (the dyed hand, and it is at the hump of the she-camel). This reflects another Bedouin tradition of envisaging a large she-camel (*nāqah*) in the stars composing the region of Cassiopeia and Andromeda (see Kunitzsch [1961], no. 190). While terms related to this camel are not found on celestial globes, the early notion of a camel in this region of the heavens is illustrated in two copies of al-Ṣūfī's treatise (Wellesz [1964], 91).

FIGURE 56.—The Lady with a Chair [Cassiopeia]. (Photo: Smithsonian no. 72-3100)

Constellation 11. *Barsā*ᵓ*ūs*, that is, the Bearer of the Ogre's Head [Perseus]

FIGURE 57

In the title *ṣūrat barsā*ᵓ*ūs wa huma ḥāmil ra*ᵓ*s al-ghūl*, which is written in two lines along the northern side of the figure, the name Perseus is transliterated as *Barsā*ᵓ*ūs*, after which it is added by way of explanation that he is the bearer of the ogre's head (see Kunitzsch [1974], 181 for various ways in which the Greek name Perseus was transliterated into Arabic). The figure holds by the hair the bearded and mustachioed head of a male demon, while in the hand raised over his head he wields a sword, which appears at first glance to resemble more a club until the hilt is noticed. Perseus is one of four bearded figures on the Smithsonian globe, not including the bearded orge's head. The artist has again drawn the figure with his hands reversed.

According to Greek tradition Perseus (περσεύς) was the son by Zeus of Danaë who, because her father had been told by an oracle that his grandson would kill him, had been set adrift on the sea with her son. They were taken in by King Polydectes, who years later contrived to send Perseus to fetch the head of the Gorgon Medusa. The Gorgons were three hideous sisters, of whom only Medusa was mortal; snakes grew on their heads instead of hair, and anyone who beheld them was turned to stone. With the aid of Athena, Perseus beheaded Medusa and carried off her head, holding it by the snakes. When the blood dripping from the head fell to earth it gave rise to Pegasus, another constellation. Before returning to King Polydectes Perseus rescued Andromeda from the sea monster Cetus and married her. In Islamicate iconography the snakes on Medusa's head became ordinary hair and the female Medusa became a male ghoul. It has been suggested by Wellesz ([1959], 9) that the blood flowing from Medusa's neck in Greek representation may have suggested a man's beard to the Arabic artists.

To the west of Perseus are to be seen the feet of his wife Andromeda, and directly above him his mother-in-law Cassiopeia. When Aratus (lines 248–253) described the constellation he mentioned him by name but did not describe him as carrying Medusa's head. However, later mythographers described him as having a sword in his right hand, Medusa's head in his left, and wings on his feet, although this is not reflected in Ptolemy's description of the figure in his star catalog. The winged boots decorated with a scale pattern he wears in Figure 57 are actually a part of typical Mughal dress.

The constellation consists of 26 formed stars and 3 unformed stars. To the left of the ghoul's head is written *ra*ᵓ*s al-ghūl* (head of the ghoul), which is intended to refer to the largest star in the head, [β Persi, Algol], a star commonly labeled on globes.

Within the blade of the sword there is written *mu*ᶜ*taṣam al-thurayyā* (the shelter of *al-thurayyā*), which is probably a mistake for *mi*ᶜ*ṣam al-thurayyā* (the wrist of *al-thurayyā*). The former reading is not known to occur elsewhere, except on globes No. 11 and No. 13, which were probably made by the same maker who produced the unsigned Smithsonian globe. The latter star name has a long tradition in the Islamic world, being used by *anwā*ᵓ authors (Kunitzsch [1961], no. 169) and on all globes except the two earliest, Nos. 1 and 34, where the label is omitted. This name refers to the star, no. 1 (actually a pair of open star clusters) in the hand of Perseus [hχ *Persei*], which was considered a nebulous group (η νεφελοειδὴς συϛροφὴ) by Ptolemy; al-Ṣūfī (*Ṣuwar*, 85) calls the star *saḥābī* (cloudy) (cf. Kunitzsch [1961], no. 169). On globe No. 26 by Ḍiyāᵓ al-Dīn of the Lahore workshop the label reads *mi*ᶜ*ṣam al-thurayyā saḥābī* (the nebulous wrist of *al-thurayyā*).

As to the significance of *al-thurayyā*, we must look again to an early Bedouin tradition over whose terminology there is superimposed the Ptolemaic image of Perseus. This concept of a large female figure named *al-thurayyā* determines the labeling of all the other stars in this constellation. The Pleiades were seen as the head
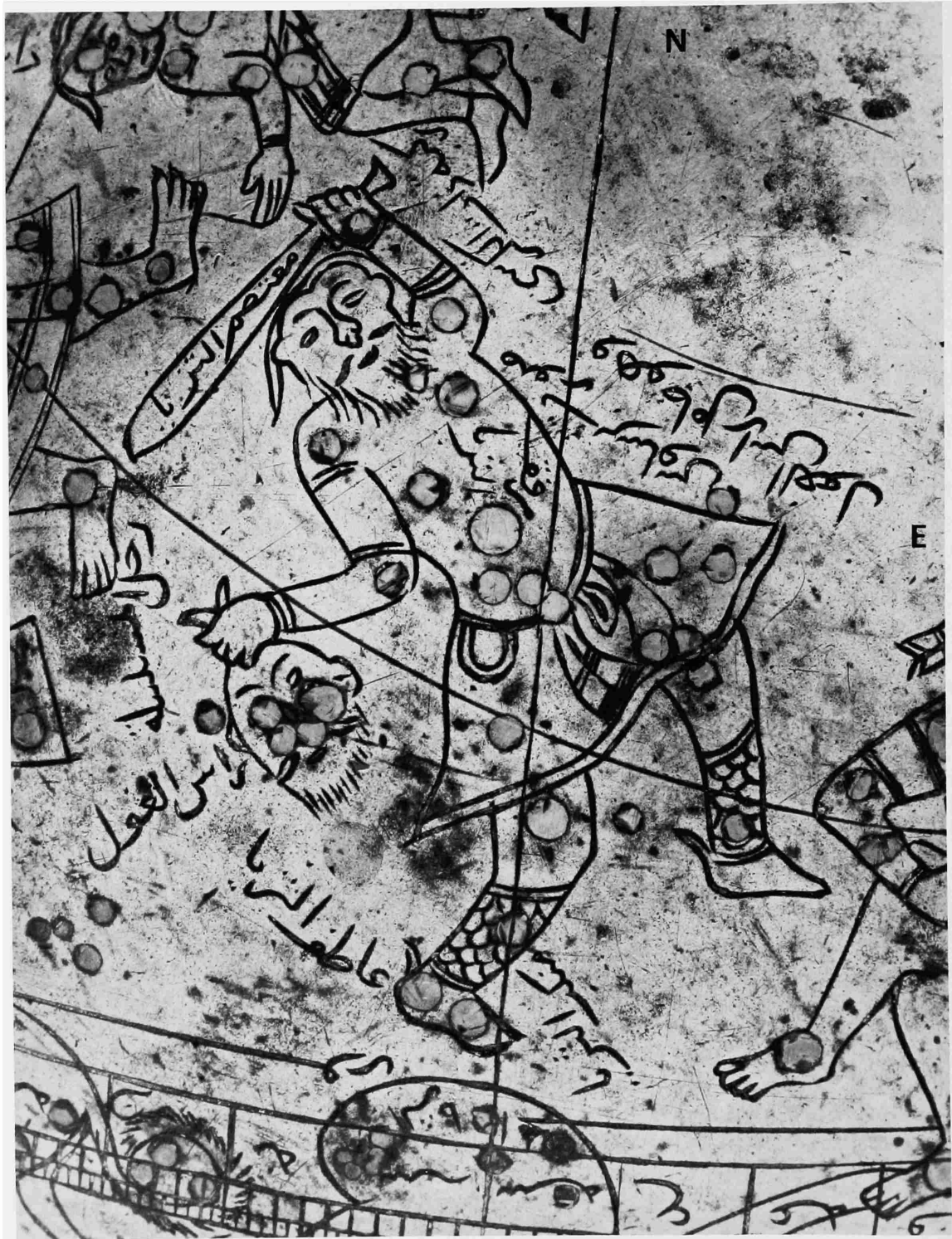
FIGURE 57.—*Barsāʾūs*, that is, the Bearer of the Ogre's Head [Perseus]. (Photo: Smithsonian no. 72-3097)

of a woman whose upper arm stretched out through Perseus with her open hand with finger tips stained with henna forming the constellation Cassiopeia. With this configuration in mind, the star (or pair of open star clusters) is called the wrist of *al-thurayyā*. The large star in the stomach of Perseus is labeled in Figure 57 *mirfaq al-thurayyā* (the elbow of *al-thurayyā* [no. 2; *α Per*, Mirfak]). The star on the shin-bone of the back leg is labeled *mankib al-thurayyā* (the shoulder of *al-thurayyā* [no. 24; *ξ Per*]). The two stars in the lower foot [nos. 25, 26; o*ζ Per*] are usually titled *ᶜātiq al-thurayyā* (the shoulder-blade of *al-thurayyā*). The Smithsonian globe reads *ᶜāṭif al-thurayyā* (which occurs on only two other globes, Nos. 11 and 13)—a certain mistake, a *ṭāʾ* having been written instead of *tāʾ*, and one dot omitted. See the discussion of Lunar Mansion 3 for further details on stars related to *al-thurayyā*.

Constellation 12. He who Holds the Reins [Auriga]

FIGURE 58

In the Greek world there were two images given to this area between the Pleiades and the Greater Bear, both described by Aratus (lines 156–166). There was seen in the area the charioteer ὁ ἡνίοχος (one who holds the reins) and also the Goat, αἴξ, which is said by Aratus to be on his left (western) shoulder, and young goats or kids, ἔριφοι, which were placed on the charioteer's waist below. The mythological significance of the charioteer and goats is obscure. Hyginus (II, 13) said the figure was called Erichthonis who first invented the four-horse chariot and first established sacrifices to Athena. Cleostratos of Tenedos is said to have first pointed out the kids among the stars. Ptolemy called the constellation ἡνίοχος (Heniochus; he who holds the reins) and the third star the goat and the eighth and ninth the kids. The goat and the kids were considered important indicators of weather. The bucolic poet Theocritus (VII, 52–54) said, for example, "fair voyage to Mitylene shall Ageanax have when the Kids stand in the evening sky and the south wind speeds the wet waves, and when Orion stays his feet upon the Ocean" ([trns.] Gow, 59). In Latin literature the constellation was called Auriga (Hyginus, II, 3; Virgil *Aeneid*, IX, 668).

In the Islamic world the Greek conception of the charioteer and the goats was quite accurately transported, unchanged, into the Arabic culture. Thus the constellation is called *ṣūrat mumsik al-aᶜinnah* (the constellation of him who holds the reins), in Figure 58 written above the head. The large star on the eastern shoulder is labeled *mankib dhī al-ᶜinān* (the shoulder having the rein [no. 4; *β Aurigae*]), from which we get the modern name Menkalinan. This is not a common label on extant globes, but does occur elsewhere (e.g., Nos. 11 and 13) and in Ulugh Bēg's copy of al-Ṣūfī's treatise (*Ṣuwar*, fig. 12).

The large star on the western shoulder is labeled *ᶜayyūq* [no. 3; *α Aur*] and is Capella, the sixth brightest star in the heavens. The meaning of the Arabic word is not clear (see Kunitzsch [1961], no. 47). The usual meaning of the Arabic root is "to delay" or "to impede." It has been suggested that it is derived from a Babylonian word *īqu* (goat), and that perhaps this word is the source for both the Greek word αἴξ and the Arabic *ᶜayyūq* (Hommel 595). The *anwāʾ* author Ibn Qutaybah (Kunitzsch [1961], no. 47) says that *ᶜayyūq* is behind *al-thurayyā* (the Pleiades) on the right side of the Milky Way, and "it is a whiter, brighter, and more brilliant star and is located much closer to the Pole than the Pleiades." Al-Ṣūfī also called Capella *raqīb al-thurayyā* (guardian of the Pleiades), since in many locations it rose at the same time.

Al-Ṣūfī (*Ṣuwar*, 91) also referred to the two stars close together on the western arm bent in toward his waist as *al-jidyān* "the two Kids" [nos. 8,9; *ζη Aur*], apparently following the Greek tradition that may have been derived from a Babylonian source. The star near the elbow of the same arm is also named "the goat," using a different word *ᶜanz*, which al-Ṣūfī stated could also apply to Capella, but more appropriately was used for the star below

FIGURE 58.—He Who Holds the Reins [Auriga]. Arrow indicates plug. (Photo: Smithsonian no. 72-3096)

[no. 7; ε *Aur*]. The asterism of these three stars [εηζ *Aur*] is even today known as "the Kids."

Thirteen stars are shown on the Smithsonian globe as being in the constellation Auriga. The star in the lower foot, which is shared with the horn of Taurus below, is given the number 11 of the constellation Auriga. What appears to be a round star above the hand on his waist is in fact a plug and not an inlaid star; it is indicated by an arrow in Figure 58. Ptolemy cataloged 14 stars in this constellation; al-Ṣūfī, however, omitted the fourteenth star of Ptolemy's listing, with the observation that he was not able to observe it. In this, al-Ṣūfī was followed by Ulugh Bēg five centuries later.

Al-Ṣūfī (*Ṣuwar* 92) also mentions that in the Bedouin tradition there were two stars between *ᶜātiq al-thurayyā* (the shoulder-blade of *al-thurayyā*), which are the two in the lower foot of Perseus to the west, and *al-ᶜayyūq* [α *Aur*, Capella] on the western shoulder of Auriga. He identifies these as being the star in the upper foot of Perseus [no. 21; e *Persei*] and the one in the upper foot of Auriga [no. 10; ι *Aur*]. He says they are called *al-mrjf* and *al-birjīs*, though which is which is not clear. The significance of these two star names is very uncertain, although some suggest that they indicate camel imagery (Kunitzsch [1961], no. 66). Neither star name is known to occur on celestial globes.

Constellations 13 and 14. The Serpent Charmer and the Serpent [Serpentarius and Serpens]

FIGURE 59

Aratus (lines 74–90) described the serpent-holder ὀφιοῦχος (Ophiuchus) as having his head toward the north, near that of "the phantom" (Hercules), with his feet trampling a monster (Scorpio). He notes that the stars on his shoulders gleam brightly while those on this hands are dimmer. Ophiuchus clutches in his two hands the ὄφις, a serpent or snake which is coiled a little about his eastern hand but is greatly coiled above his western hand with its jaw turned toward Corona Borealis. Later mythographers (e.g., Erat. *Catast.*, 4) identified Ophiuchus with Asclepius and so with the art of healing.

In Figure 59 to the east of the head is written *ṣūrat al-ḥawwā* (the constellation of the serpent charmer), which consists of 24 formed stars and 5 unformed ones. The large star in the head, no. 1, is labeled directly over the head *raʾs al-ḥawwā* (the head of the serpent charmer), from which we get the modern name Ras Alhague [α *Ophiuchi*]. This is not a common term on Class A globes prior to the Lahore workshop, although al-Ṣūfī uses it and considered it an astrolabe star. The usual Arabic designation for this star on early globes is *al-rāᶜī* (the shepherd), a term that is also engraved on the Smithsonian globe to the east of the head, near the graduated celestial equator which can be seen passing across his chest. The star nearest this word on the Smithsonian globe is no. 5 of the unformed stars [Flam. 72, *Oph*], a star considered of fourth magnitude. Since stars of this magnitude were seldom given special names, the name must surely be intended to apply to the large star in his head [α *Oph*], in keeping with all the astronomical literature (Kunitzsch [1961], no. 276).

Al-Ṣūfī (*Ṣuwar*, 102) adds that there are two dogs near the shepherd. One of the dogs is the higher and larger of the two stars on the eastern shoulder [no. 2; β *Oph*] called *Kalb al-rāᶜī* (the shepherd's dog). The other is the star in the head of Hercules [α *Herculis*]. This probably reflects a Bedouin tradition, although no source but al-Ṣūfī mentions it (see Kunitzsch [1961], no. 143). The dogs of the shepherd are not labeled on the Smithsonian globe.

The serpent in Figure 59 was titled beneath the head near the missing piece of the globe, [*ṣūrat*] *ḥayyat al-ḥawwā* (the Constellation of the Serpent Charmer's Serpent). On this globe there appear to be only 15 stars in the Serpent itself. However, three (nos. 1, 4, 5) were placed in the area now missing, bringing the original total to 18 formed stars, corresponding with the number in the catalogs.
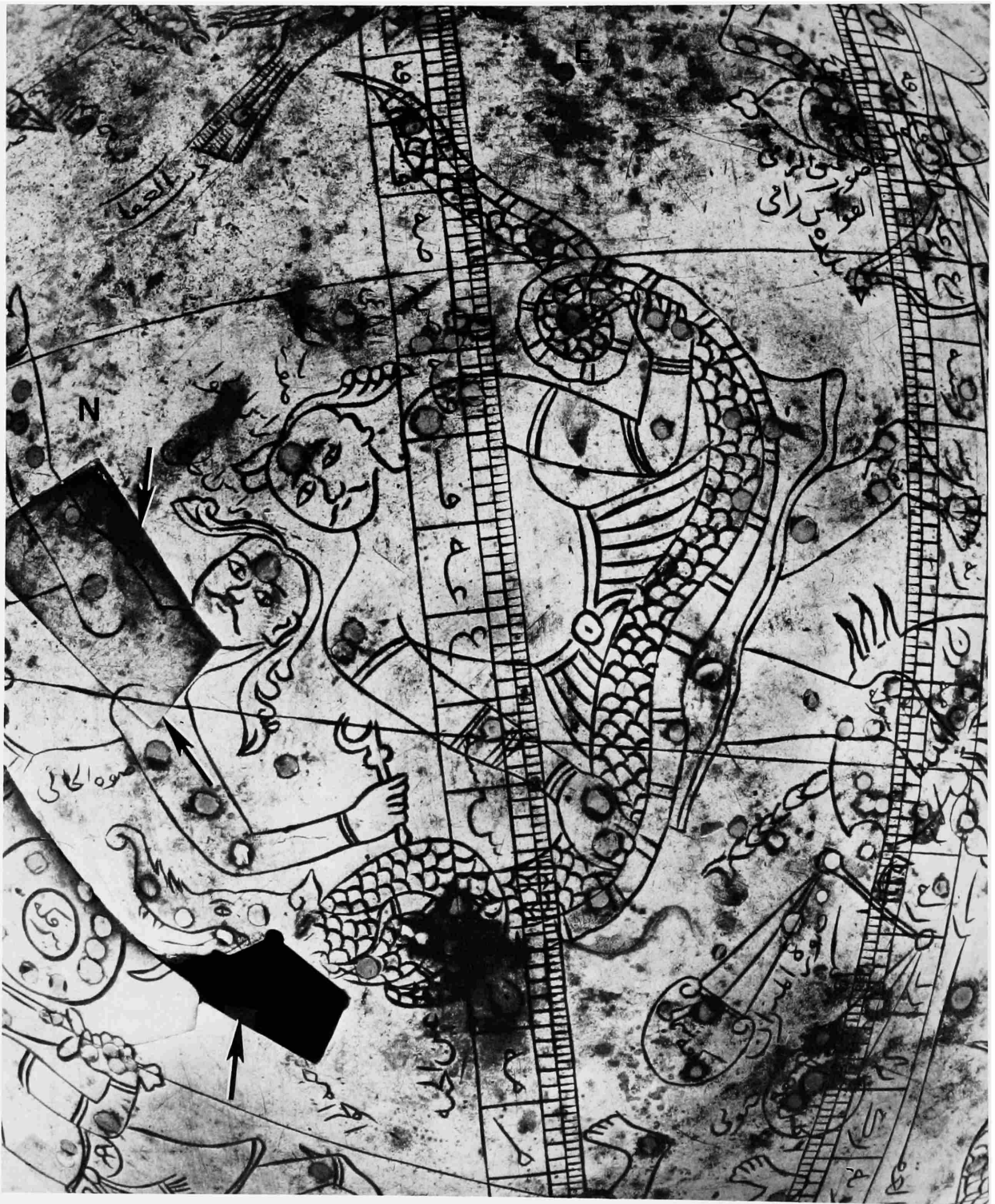
FIGURE 59.—The Serpent Charmer and the Serpent [Serpentarius and Serpens]. Arrows indicate plugs (one is missing). (Photo: Smithsonian no. 72-8587)

In Figure 59 there is one star labeled on the serpent, one that is difficult to see for it is located in the badly tarnished area in the western coil. The star to which the label refers is no. 9 of the serpent [*α Serpentis*], clearly labeled *ᶜayn al-ḥayyah* (the eye of the serpent). This label is quite certainly an error, for the eye of the serpent is nowhere near, and this name occurs in no other globe or text. The maker must mistakenly have thought of the word *ᶜayn* (eye) when seeing the word *ᶜunq* (neck), which differs from the word for eye by only the placement of diacritical points and a slightly different formation of the last letter. In any case, this star is called *ᶜunq al-ḥayyah* (the neck of the serpent) by al-Ṣūfī (*Ṣuwar*, 107) and on all globes studied except the two earliest (nos. 1 and 34), where it is not labeled. The modern name of the star is Unuk, clearly derived from *ᶜunq*.

In reference to the fourth star of the serpent [*β Ser*; a star which should be where the piece is missing], al-Ṣūfī says "the place where the neck begins, i.e., the beginning of the Northern Row" (*al-nasaq al-shaᵓāmī*). While not appearing on the Smithsonian globe, this name refers to the Bedouin notion of a Northern Row of stars which includes two in the serpent [*βγ Ser*], the stars across the arms of Hercules and two in Lyra, which form the edge of a meadow. See the discussion of Figure 54 (Hercules) for further details.

Of the seventh star of the serpent (the high, very visible star in the western coil; *δ Ser*), al-Ṣūfī remarks that it is "the beginning of the Southern Row," which is another row of stars, south of the one through Hercules. It is composed of four stars in the tarnished area of Serpens [nos. 7,8,9,10; *δλαε Ser*], two stars in the western hand of Serpentarius [nos. 7,8; *δε Oph*], the star in the serpent southeast of the western hand of the serpent-charmer [no. 12; *υ Oph*], and the star near the hem of the serpent charmer's pleated skirt and the two uppermost stars of his eastern leg [nos. 12, 19, 13; *ηζξ Oph*]. The area between the Northern and Southern Rows was called *al-rawḍah* (the meadow), where the shepherd and his two dogs roamed (al-Ṣūfī *Ṣuwar*, 102). In Figure 59 on each foot of Serpentarius is a name of a lunar mansion which applies to an interval of the ecliptic (see Lunar Mansions 19 and 20).

Constellation 15. The Arrow [Sagitta]

FIGURE 60

Aratus (lines 311–312) says that above Sagittarius, the archer, is an arrow (ὀϊστός) alone without a bow. In Figure 60 Sagittarius cannot be seen, but would be to the south (right) of the small bird. The arrow has been associated with the legend of Hercules killing the eagle gnawing the liver of Prometheus. In the Islamic world the name was usually translated *sahm* (arrow) as in Figure 60. The globes of the eleventh century (Nos. 1 and 34) use the word *ᶜanajah*, which means javelin. The constellation consists of five stars in a nearly straight line. No stars are greater than fourth magnitude, and none bear special names.

Constellation 16. The Eagle [Aquila]

FIGURE 60

Aratus (lines 312–315) says that near Cygnus, whose head is seen at the north side of Figure 60, "another bird tosses in storm, of smaller size but cruel in its rising from the sea when the night is waning, and men call it the Storm-bird (ἀήτος)" ([trns.] Mair, 231). The later word used was αἐτός (an eagle). The eagle (Hyginus II,16) was interpreted as either that killed by Hercules or the eagle Zeus used to carry Ganymede to Olympus. In Figure 60 the title reads *ṣūrat ᶜuqāb* (the constellation of the eagle), a simple translation of the Greek αἐτός. It consists of nine formed stars and six unformed ones, which are south of the celestial equator passing through Aquila, with one in the graduations. Al-Bīrūnī (*Astrol.*, sec. 160) says the eagle is lighting upon the arrow, and indeed on Smithsonian globe, Aquila does appear to be landing upon Sagitta. On the earliest Arabic globes the eagle actually sits on the arrow.

FIGURE 60.—The Arrow [Sagitta], the Eagle [Aquila], the Dolphin [Delphinus], and the Part of a Horse [Equuleus]. (Photo: Smithsonian no. 72-3087)

Written on the breast of the eagle is the word *ṭāʾir* (the flying bird) and applies to the large star on the upper part of the northern wing. [no. 3; *α Aquilae*]. This is the eleventh brightest star, and the Arabic term is the source for the modern name Altair. A Bedouin tradition (al-Ṣūfī, *Ṣuwar*, 111) applied the name *al-nasr al-ṭāʾir* (the flying eagle) to three bright stars in a row: *α Aql*; the large star in the head [no. 2; *β Aql*]; and the large star on the inside edge of the northern wing [no. 5; *γ Aql*]. Al-Ṣūfī also applies the name "the flying eagle" to the constellation as a whole, while al-Bīrūnī (*Astrol.*, sec. 163) restricts it to the brightest star, *α Aql*. It may be that there was a Babylonian common antecedent for both the Greek and Bedouin concepts of an eagle for this region of the sky (Hommel, 595; Kunitzsch [1961], no. 194a). The ninth star, in the tail, is labeled in Figure 60 *dhanab al-ᶜuqāb* (the tail of the eagle). This is not known to occur on any globe prior to those made in Lahore.

Constellation 17. The Dolphin [Delphinus]

FIGURE 60

Aratus (lines 316–318) speaks of "the Dolphin (δελφίς) with few bright stars and body wreathed in mist, but four brilliants adorn him, set side by side in pairs" ([trns.], Mair, p. 231). One legend has it that the dolphin was placed in the heavens by Poseidon as a reward for persuading Amphitrite to marry Poseidon (Erat. *Catast.*, 31). Others say it is the dolphin who bore Arion the citharist (a poet of the late seventh century BC) to shore safely when servants wishing to kill him threw him overboard.

The Arabic name, written near the mouth in Figure 60, is *ṣūrat al-dālfīn*, a transliteration of the later Greek form of the word for dolphin δελφίν (see Kunitzsch [1974], 186). Al-Bīrūnī (*Astrol.*, 160) says that *al-dālfīn* is a marine animal that resembles an inflated wine-skin (*al-ziqq al-manfūkh*). The constellation contains 10 formed stars, of which only one is named on the Smithsonian globe—the largest of the three in the tail, labeled *dhanab al-dālfīn* (tail of the dolphin [no. 1; *ϵ Delphini*]).

The four bright stars that form a rhomboid mentioned by Aratus are the four large ones toward the front of the dolphin [nos. 4,5,6,7; *βαδγ Del*]. These four were in the Bedouin tradition called *al-qaᶜūd*, which is difficult to translate, but seems to mean "the young camel" (see Kunitzsch [1961], no. 234). There are variant readings for the word, such as *al-ᶜuqud* (necklace). Another Bedouin tradition gave the name *al-ṣalīb* (the cross) to these same four stars. In keeping with this image al-Ṣūfī (*Ṣuwar*, 116) also called the star in the tail [*ϵ Del*] *ᶜamūd al-ṣalīb* (the column of the cross). Al-Bīrūnī [*Astrol.* sec. 163) speaks of *ṣalīb al-ṭāʾir* (the cross of *al-ṭāʾir* [*α Aquilae*]). This asterism is known today as Job's Coffin. Another group of four stars was given the parallel name *ṣalīb al-wāqiᶜ* (the cross of *al-wāqiᶜ* [*α Lyrae*]). Al-Ṣūfī (*Ṣuwar*, 63) identifies this as no. 19 of Hercules [*ι Herculis*] and nos. 3,5,4 of Draco [*βγξ Draconis*]. Later writers identify it with the "camel-mothers" in Draco [*νβξγ Draconis*; see Kunitzsch [1961], no. 278].

Constellation 18. Part of a Horse [Equuleus]

FIGURE 60

The constellation having the form of a head of a horse is not mentioned by Aratus. It is called by Geminus and Ptolemy ἵππου προτομή, meaning the front part of a horse. It can be seen immediately above the Dolphin. In Figure 60 it is labeled near the muzzle *qiṭᶜat al-faras* (the part of a horse). Al-Bīrūnī (*Astrol.*, sec. 160) calls it "the first horse" in reference to Pegasus, whose head can be seen next to this constellation. Equuleus is composed of four obscure stars, none of which are given individual names.

Constellation 19. The Larger Horse [Pegasus]

FIGURE 61

Aratus (lines 205–215) wrote of this constellation after describing Andromeda, whose head can be seen in the upper corner of Figure 61 ([trns.] Mair, 223, 225):
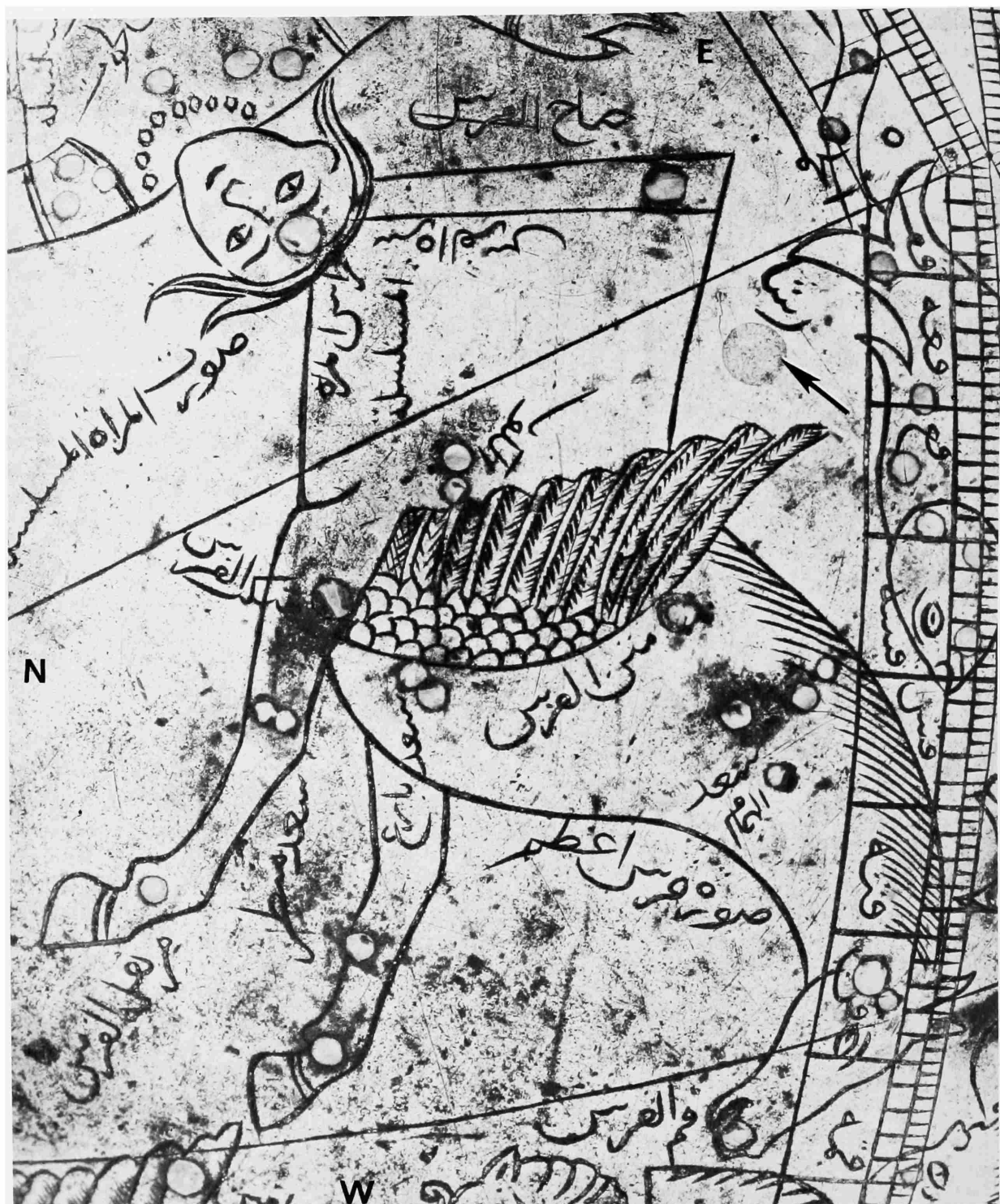
FIGURE 61.—The Larger Horse [Pegasus]. (Photo: Smithsonian no. 72-3088)

Beneath [Andromeda's] head is spread the huge Horse, touching her with his lower belly. One common star gleams on the Horse's navel and the crown of her head. Three other separate stars, large and bright, at equal distance set on flank and shoulders, trace a square upon the Horse. His head is not so brightly marked, nor his neck, though it be long. But the farthest star on his blazing nostril could fitly rival the former four, that invest him with such splendor. Nor is he four-footed. Parted at the navel, with only half a body, wheels in heaven the sacred horse.

Later mythographers (e.g., Hyginus II, 18; Erat. *Catast.*, 18) associated the horse with Pegasus, the offspring of Poseidon and the Gorgon Medusa and the horse used by Bellerophon, as well as with Melanippe, who was the daughter of Chiron the Centaur, who when born was placed in the skies by the gods so that Chiron (Centaurus) could not see her and with only half a body so that her sex could not be determined. Aratus had not mentioned wings, and Eratosthenes (*Catast*, 18) notes that Pegasus's flight is unbelievable since it has no wings. But by Ptolemy's time wings were clearly a part of the constellation.

In Arabic this Ptolemaic front half of a winged horse is most frequently called "the larger horse" (*faras a^cẓam*), as is written in Figure 61 along the neck. The larger horse is also occasionally called "the second horse" (*al-faras al-thānī*) as on globes Nos. 1 and 34. (Equuleus was the first horse). It was also known as the "winged horse" (*faras mujannaḥ*). It consists of 20 formed stars. A medium-sized plug is seen in Figure 61 near the tip of the wing. The bright star on its nostril, no. 17, is labeled *fam al-faras* (the mouth of the horse). This star is also called *anf al-faras* (the nose of the horse) on globe No. 3. The star is ε *Pegasi*, whose modern name Enif is derived from the Arabic word for nose (cf. Kunitzsch [1974], 259).

The square formed by the four bright stars was called by the Bedouins *al-dalw* (the bucket). See discussion of Lunar Mansions 26 and 27 for this traditional Arab asterism. These are known today as the Square of Pegasus. The star at the upper edge of the wing [no. 4; α *Peg*] is labeled in Figure 61 *matn al-faras* (side of the horse). The star near the join of wing and lower leg [no. 3; β *Peg*] is labeled *mankib al-faras* (shoulder of the horse). The star in the southeast corner of the body [no. 2; γ *Peg*, Algenib] is named *jināḥ al-faras* (wing of the horse), while the one shared with the head of Andromeda [no. 1; δ *Peg* or α *Andromedae*, Sirrah] bears two labels: *surrat al-faras* (navel of the horse, the source of the modern name), and *ra'^s al-mar'ah al-musalsalah* (head of the chained woman, referring to Andromeda). This latter star is numbered as a star in Pegasus. These individual names of the four stars composing the square all reflect the Ptolemaic image rather than the earlier Bedouin imagery.

The traditional image of the leather bucket is evident on the Smithsonian globe in the title given the pair of stars close together at the back of the wing [nos. 5,6; τυ *Peg*]. The inscription appears to read *al-kūb* (the cup; written in an identical manner on globes Nos. 11 and 13 by the maker of this unsigned globe), but this is surely an error for *al-karab*, which differs only slightly in the formation of the middle letter. *Al-karab* means the place where the rope is attached to a bucket, and was used by al-Ṣūfī (*Ṣuwar*, 122) in reference to these two stars.

There are in addition three groups of two stars, each bearing traditional Arab labels on the Smithsonian globe. These are three of the 10 groups of *sa^cd* stars, *sa^cd* being roughly translated as omen. The attachment of *sa^cd* to certain stars is very ancient and its meaning obscure; consequently it is best to leave it untranslated (see discussion of Lunar Mansions 22–25 for further details on the *sa^cd* stars). The two largest of the four stars grouped together on the neck are labeled *sa^cd al-humām* (*sa^cd* of the hero; but could also mean *sa^cd* of the sleet or hail [nos. 11,12; ζξ *Peg*]). On the stomach between the two legs, two stars are labeled *sa^cd bāri^c* (an excellent *sa^cd* [nos. 9,10; λμ Peg]). The two stars together on the lower leg are named *sa^cd maṭar* (a rainy *sa^cd* [nos. 7,8; ηο *Peg*]). Al-Ṣūfī calls the two in the head [θν *Peg*] *sa^cd al-bihām* (*sa^cd* of the young animals [see Kunitzsch [1961], no. 257, 2a, 2b, 2c for variants]). But this last term is not pro-

vided on the Smithsonian globe.

The star near the hoof of the lower leg [no. 18; π *Peg*] bears an undecipherable inscription: *mrhlat al-faras*. This star does not bear an individual name in any of the literature or on other studied globes, with the exception of Nos. 11 and 13, which have the same words and are no doubt made by the same maker who produced the Smithsonian globe.

Constellation 20. The Chained Woman [Andromeda]

FIGURE 62

Aratus (lines 197–204) described Andromeda (ανδρόμεδα) as having her arms outstretched and bearing bonds or fetters (δεσμά), for according to legend she was bound to a rock as a sacrifice to the sea-monster Cetus, by her parents Cassiopeia and Cepheus, until she was rescued by Perseus, whose figure can be seen beneath Andromeda's.

In Figure 62 she is depicted with her arms outstretched, but with no chains. Occasionally on globes she is depicted wearing chains: on No. 3 they are between her hands, and on No. 26 they are between her feet. To the south along her side is the northern of the two fishes comprising the constellation Pisces. Two additional representations of Andromeda are found in al-Ṣūfī manuscripts, in which a fish lies across her feet or across her body. These conceptions are drawn from the Bedouin rather than the Ptolemaic traditions and do not appear on any known globe.

The constellation contains 24 formed stars including the one which in Figure 62 is outside the figure, above the northern hand. The star on her head [α *Andromedae*] is counted in the star catalogs as a star of Pegasus, so that the total of formed stars for this constellation in the catalogs is 23, with no unformed stars. A medium sized plug can be seen under the north arm.

The title written near the northern side of her head reads *ṣūrat al-marᵓah al-musalsalah* (the constellation of the chained woman), which is the the usual designation. Al-Ṣūfī (*Ṣuwar*, 125) adds, however, that she is also called *al-marᵓah allatī lam tarra baᶜlan* (the woman who never had a husband) in an attempt to derive the name Andromeda from ἄνδρα μὴ εἰδε (she who does not know a man) (cf. Kunitzsch [1974], 187–188). The star in her head [α *And* or δ *Pegasi*; Sirrah] is labeled *raᵓs al-marᵓah al-musalsalah* (the head of the Chained Woman) and also *surrat al-faras* (navel of the horse), for it is shared with Pegasus.

The star on her waist near the fish is given two names as well: *janb al-musalsalah* (the side of the Chained One) and *baṭn al-ḥūt* (belly of the fish [no. 12; β *And*, Mirach), the first reflecting the Ptolemaic form and the latter the Bedouin image of a large fish. The latter name was given also to the twenty-eighth lunar mansion (see section on Lunar Mansions). Al-Ṣūfī (*Ṣuwar*, 126) also called the star, in addition to the two previous names, *al-rishāᵓ* (the rope) which is also a name for the twenty-eighth lunar mansion. In this Bedouin image the rope was furnished for the leather bucket which was seen in the asterism of the Square of Pegasus.

On the Smithsonian globe *rijl al-musalsalah* (the foot of the Chained One) is the title given the star in her eastern foot [no. 15; γ *And*]. While this Ptolemaic name is not common on Class A globes, it does occur on Mughal globes e.g., Nos. 11 and 13). Al-Ṣūfī (*Ṣuwar*, 126) says it is given this name on astrolabes, and it occurs on Ulugh Bēg's personal copy of al-Ṣūfī's treatise (see Wellesz [1959], figure 70). The traditional Bedouin term for the star was *ᶜanāq al-arḍ* (the wild lynx), which gave rise, rather circuitously, to the modern name of the star, Almach (see Kunitzsch [1961], no. 34a, 34b). The latter term occurs on some early globes (e.g., Nos. 3, 4, and 5).

Al-Ṣūfī (*Ṣuwar*, 132–134) appended to his discussion of Andromeda a description and illustration of three early Bedouin constellations—two different fishes overlapping Andromeda and a complete horse (*al-faras al-kāmil*). In these discussions al-Ṣūfī clearly described the Andromeda Nebula (M31), which would be located about

FIGURE 62.—The Chained Woman [Andromeda] and the Triangle [Triangulum]. (Photo: Smithsonian no. 72-3085)

where the plug under Andromeda's arm is on the Smithsonian globe, but he did not place it in the catalog. It is not known to be indicated on any extant globe, though it is shown in some illustrations of the fish in Andromeda in al-Ṣūfī manuscripts (see Wellesz [1965], plate 14).

Constellation 21. The Triangle [Triangulum]

FIGURE 62

The constellation, following Ptolemaic specifications, consists of four stars. Aratus called it δελτωτόν, and mythographers (Hyginus, II, 19) suggested that Hermes placed it above the head of Aries so that its brightness would mark the dimness of Aries and so that its triangular shape would form the first letter of the name for Zeus (Δίs, an older form of Ζεύs). While the constellation bears no formal title in Figure 62, the star at the top of the triangle is called *raʾs al-muthallath* (the apex of the triangle [*α Trianguli*]). Al-Ṣūfī adds that this star, together with the most northerly of the three at the base, were traditionally called *al-anīsān* (the two friends) [*αβ Tri*]. While this name does not appear on the Smithsonian globe, on globe No. 5 the name *al-anīsān* is inlaid in silver while *raʾs al-muthallath* (the apex of the triangle) is merely engraved, in an attempt to indicate that the former is the older, more traditional term within the Arabic world, and the latter the later, secondary designation.

Constellation 22. The Ram [Aries]

FIGURE 63

Aries the Ram is the first of the zodiacal signs, having been at one time the sign in which the vernal equinox occurred. Due to precession, however, the equator and ecliptic on the Smithsonian globe meet in the constellation of Pisces instead of Aries. The first segment of the zodiac (1° to 30°) after the junction marking the vernal equinox is still labeled *al-ḥamal* (the young ram), written on the north side of the ecliptic in long stretched out letters, for this segment of the ecliptic is, for astrological purposes, the House of Aries. The segment of the zodiac in which the constellation Aries, or most of it, occurs on the Smithsonian globe is labeled *al-thaur* (the bull, or Taurus). Thus the line separating the House of Aries from the House of Taurus passes through the horns and near front leg of the constellation Aries. On the southern side of the ecliptic three names of lunar mansions can be seen: in front of the forward knee of Aries there is *buṭayn*, the second lunar mansion; beneath the belly *thurayyā*, the third lunar mansion; and near the tail of Aries is *dabarān*, the fourth mansion (see the section in Chapter 5 on Lunar Mansions).

Aratus (lines 225–232) placed the Ram, κριόs, near Andromeda and the Triangle. This is the legendary Ram that bore the golden fleece, the object of the Argonaut's quest; it was the Ram that carried Phrixus and Helen through the Hellespont (Hyginus, ii.20). The Ram was sacrificed to Zeus, who placed it among the heavens, though others say (Erat. *Catast.*, 19) that the ram gave its golden fleece to Phrixus as a memorial and then passed up to the heavens of its own accord. Hyginus (II, 20) adds the story that when Dionysus attacked Africa the army found themselves without water. A ram showed them the way to water, for which reason Dionysus placed the ram in the heavens so that when the sun was in that constellation all living things would be refreshed and so that it would be the chief of all the signs since it had been the best leader of his army.

In Figure 63 we see a faithful rendition of the classical form of the constellation. A fairly large plug in the globe can be seen across his front leg. Overhead the ram is labeled *ṣūrat al-ḥamal* (the constellation of the young ram). The constellation consists of 13 formed stars and 5 unformed ones. Of the unformed, four are in a group over the rump and one is on top the head. Al-Ṣūfī observed an additional formed star in the back rear upper leg, but did not number it nor enter it in his catalog, nor is it indicated on the globe.
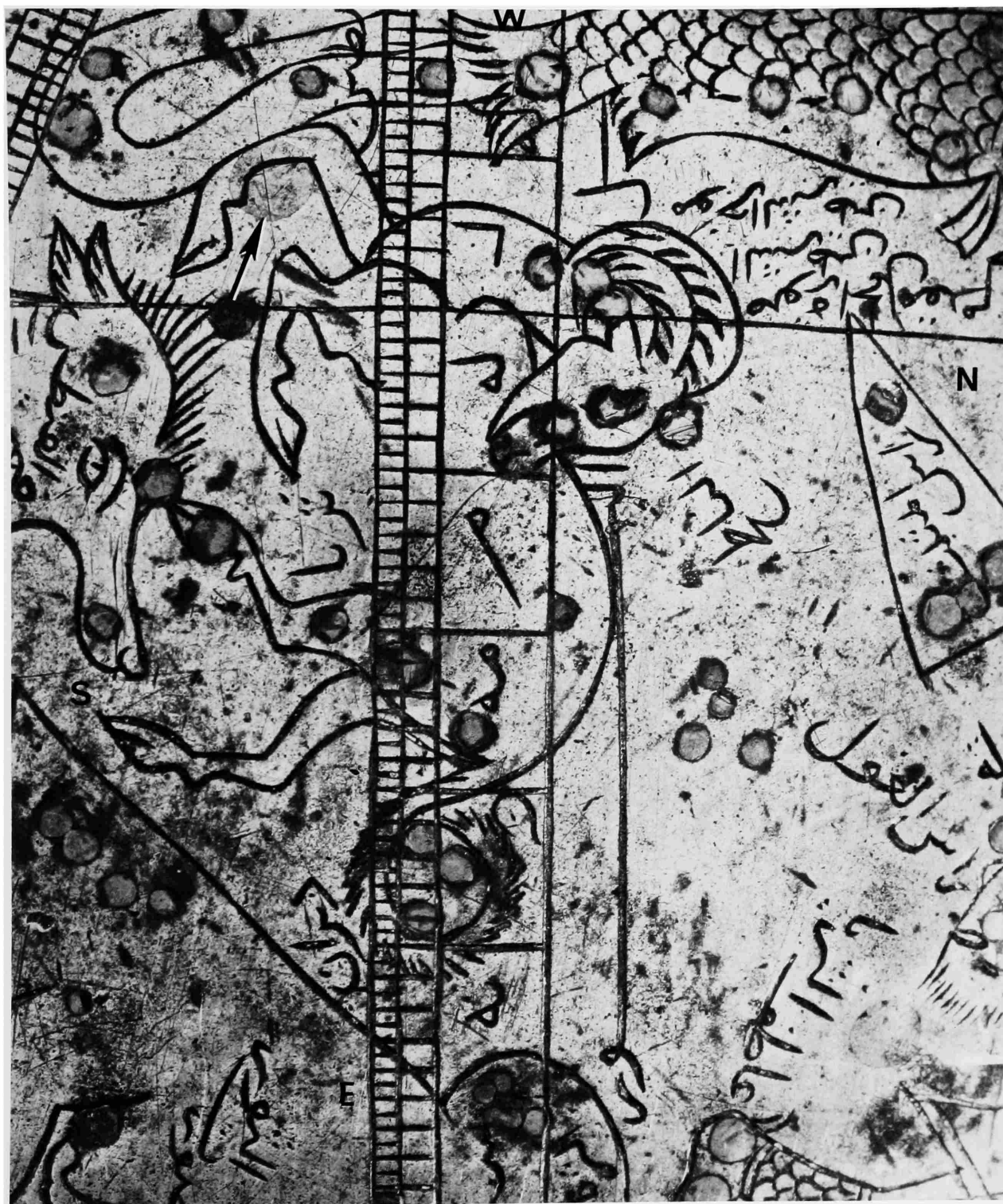
FIGURE 63.—The Ram [Aries]. (Photo: Smithsonian no. 72-3089)

In Figure 63, three stars are labeled, all reflecting traditional Arab imagery. Of the two stars very close together in the horns, the one closest to the outside of the horns is called *muqaddam al-sharaṭayn* (the anterior one of the two signals). This star is no. 1 of the constellation [*β Arietis*]. The second star of the pair in the horns is labeled *mu˒akhkhar al-sharaṭayn* (the posterior of the two signals) and refers to no. 2 of Aries [γ Arietis]. The name *al-sharaṭayn* (the two signals) is the name of the first lunar mansion, which derived originally from these two stars. On the Smithsonian globe, however, the former names apply just as star-names, while the title *al-sharaṭayn* is written as a lunar mansion at 13° House of Aries, rather than in the constellation of Aries. The star at the base of the tail, the first star of the three encircled by the tail, and the star on the back thigh form a triangle, which also gave rise to a lunar mansion. The name of the mansion is not written in the constellation of Aries as a star name, but only along the ecliptic at 25½° House of Aries (just before the knee of the constellation Aries), where it reads *al-buṭayn*, the second lunar mansion.

The large star at the top of the head, the first of the unformed stars, is labeled in Figure 63 *al-nāṭiḥ* (that which butts or gores). This is *α Arietis*, whose modern name Hamal derives from the word for ram used for the entire constellation. Al-Ṣūfī (*Ṣuwar*, 142) used *al-nāṭiḥ* for a star name, while most of the writers in the Arabic world used it as another name for the first lunar mansion (cf. Ideler, 132; Kunitzsch [1961], nos. 198, 199, 200). See the section on Lunar Mansions for further details on such star names.

Constellation 23. The Bull [Taurus]

FIGURE 64

According to Aratus (lines 167–178) the Bull, *ταυρος*, is found crouching at the feet of the charioteer, who can be seen in the upper left-hand corner of Figure 64, and with whom Taurus shares a star. Aratus adds that the Bull's head is well marked by the group of stars called the Hyades. This star group was one of the ones mentioned by Homer (*Il.*, XVIII, 486) as were the Pleiades (*Od.*, V, 272), which are also in Taurus. The legend of Europa and the bull was commonly linked to this constellation (e.g., Hyginus, II, 21). In the star group of the Hyades, Hesiod (frag. 60) names only five stars: Phaisule, Koronis, Klaeia, Phaio, and Eudora, and for him (*Works and Days*, 615) their cosmical setting was a time for ploughing. Later mythographers (Hyginus, II, 21) counted seven Hyades and made them nymphs who nursed Dionysus. They were named Eudora, Ambrosia, Koronis, Pedile, Polyxo, Phyto, and Thyone. They were also said to be sisters who cried themselves to death when their brother Hyas was killed hunting. The word Hyades (ὑάδες) is according to some derived from ὕειν (to rain), although others give an alternative derivation from ὗς (swine), since it was sometimes thought to be a sow with four young (Neugebauer *OCD*, 282). Cicero (*Nat. deo.*, II, 43) says the word comes from *hyein*, for they bring rain "while our nation stupidly names them the Suckling-pigs, as though the same Hyades were derived from the word for 'pig' and not from 'rain.'" For legends of the Hyades, see Martin ([1956], 79–89).

In Islamic representations only the first half of a charging bull is depicted, following Ptolemy's description (ἐν τῇ ἀποτομῇ). In Figure 64 the line dividing the zodiacal House of Taurus from the House of Gemini passes through the body of Taurus, so that the constellation actually occupies the area between about 50° and 80° along the ecliptic. Three lunar mansions are written along the ecliptic: one at the back of Taurus under the tail of Aries, *dabarān*; *haqᶜah* written near the head of Taurus; and *hanᶜah* between the horns. These are Lunar Mansions 4, 5, and 6, respectively. In the middle of the bull is written *ṣūrat al-thawr* (the constellation of the Bull).

The cluster of five small stars, the Pleiades, on the shoulder of the Bull are called *al-thurayyā* roughly translated as "the brilliant gem"—a
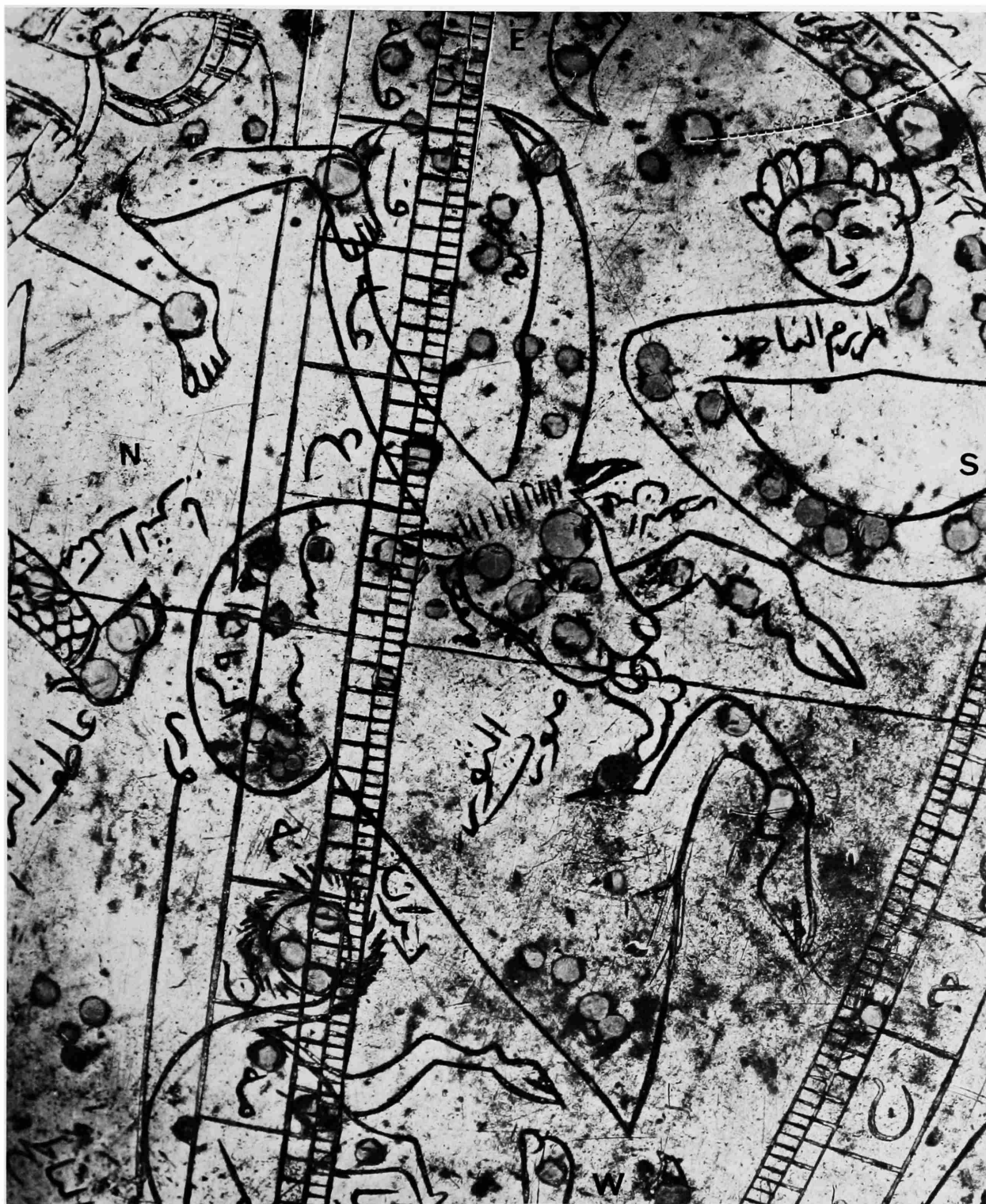
FIGURE 64.—The Bull [Taurus]. (Photo: Smithsonian no. 72-3095)

name also used for the third lunar mansion of which the Pleiades formed the central part (see discussion of Lunar Mansion 3; included are Greek accounts of this asterism). Ptolemy, al-Ṣūfī, and Ulugh Bēg all list only four stars making up the Pleiades. However, al-Ṣūfī adds that in the space within the group there were two or three stars in addition to the four, like a cluster of grapes (*ᶜunqūb al-ᶜinab*) (cf. Ideler 137, 390). Al-Ṣūfī (*Ṣuwar*, 151) explains "the stars of the Pleiades exceed these 4 which we have mentioned, but I confined myself to these 4 because they are very close and the 4 are of sufficient greatness in magnitude so that they are cited and their names not omitted," adding that the Arabs also considered it to have the dignity of one star which they called *al-najm* (the Star *par excellence*). They also called it *nujūm al-thurayyā* (the stars of *al-thurayyā*). The Smithsonian globe curiously has clearly inlaid five stars for the Pleiades.

The largest star of the five on the head is labeled *ᶜayn al-thawr* (the eye of the bull). It was numbered fourteenth in Taurus and is the thirteenth brightest star in the heavens [*α Tauri*, Aldebaran]. Al-Ṣūfī (*Ṣuwar*, 154) says it is a bright red large star traditionally called *al-dabarān* from a root meaning "to follow," because it followed the Pleiades, adding that *al-dabarān* is the name of the fourth lunar mansion and is used on astrolabes. The maker of the Smithsonian globe used the name "eye of the bull" for the star, reserving *dabarān* for the lunar mansion. The open cluster called the Hyades in the Greek world are represented by a group of five stars in the face of the bull, the brightest being *al-dabarān* [nos. 11, 12, 13, 14, 15; $\gamma\delta^{1}\theta^{1,2}\alpha\epsilon$ *Tau*]. Al-Ṣūfī recorded an additional four stars in this group, two between each pair of large ones, one being just outside the face, none of which he entered in his catalog. Another traditional name for Aldebaran was *al-fanīq*, the camel-stallion, because, as al-Bīrūnī (*Chron.* [trns.], 344) said, they called the stars around it (the other Hyades) the young camels (*al-qilāṣ*).

The star in the northern horn, which is shared with Auriga, is not counted among the stars of Taurus, thus giving a total of 32 formed stars for Taurus. The Smithsonian globe has 34 inlaid stars, one of which is the star in the northern horn [*β Tau*] and one an extra Pleiade. There are 11 unformed stars, one near the western hoof of the bull (in the line of single degree graduations of the equator), two above the head of Orion whose figure is beneath the bull's horns, and eight between the horns, extending into the line of the ecliptic.

Constellation 24. *Al-Jawzāᵓ*, or The Twins [Gemini]

FIGURE 65

The twins, which Aratus (line 147) called *δίδυμοι*, were identified by later mythographers with various pairs including Apollo and Heracles, and Castor and Pollux. The latter were the most affectionate of all brothers and were placed in the heavens as a record of unselfish friendship (Hyginus, II, 22). The myth of Castor and Pollux gave rise to the modern names for the two most prominent stars in the constellation. The twins were described in Greek literature as one having his arms around the other, as they appear in Figure 65. The constellation of the twins seems to go back to Babylonian texts (see Gundel & Böker, cols. 522–528).

The figure of Gemini is drawn in the zodiacal House of Cancer, the name of which (*al-saraṭān*) is written along the north side of the ecliptic. The line dividing the House of Gemini from that of Cancer passes through the feet of the western twin. Three lunar mansions are inscribed along the ecliptic: *dhirāᶜ*, the seventh mansion derived from stars in the constellation of Gemini, is written north of the ecliptic at the division of the House of Cancer and Gemini (the summer solstice); *nathrah*, the eighth mansion, is written on the stomach of the second twin, marking the point at 103° of the ecliptic; and *ṭarf*, the ninth mansion, is engraved south of the ecliptic between the easternmost hand of the twins and Cancer the crab, marking the point at 115¾°.

FIGURE 65.—*Al-Jawzā*ʾ or the Twins [Gemini]. (Photo: Smithsonian no. 72-8588)

The constellation is titled *ṣūrat al-jawzāʾ* (the constellation *al-jawzāʾ*). The meaning of *al-jawzāʾ* is somewhat obscure. It comes from a root meaning "to marry" and is the traditional Bedouin name for the region, as al-Bīrūnī (*Astrol.*, sec. 159) notes. The name *al-jawzāʾ* possibly referred to a large feminine figure envisioned in this region of the heavens in pre-Islamic Arabia (see section on Classical Greek and Pre-Islamic Sources and Kunitzsch [1961], 23–25). Al-Ṣūfī (*Ṣuwar*, 160) employed the name *al-tawʾamān* (the two twins) for the constellation. This name is the Arabic translation of the Ptolemaic δίδυμοι (twins) and occurs on the early globes (Nos. 1 and 34) as well as some later ones (No. 31). For the most part, however, later astronomers returned to the early Bedouin name for the region (*al-jawzāʾ*) for the name of the constellation as well as the corresponding zodiacal house.

Gemini is composed of 18 formed stars and seven unformed ones. Of the unformed ones, one is west of the western hand of the second (eastern) twin, one is west of the forward foot of the first (western) twin, one between the legs of the two twins, and four near the eastern arm of the back twin. The small dot between the legs of the eastern twin is in fact only a smudge on the surface of the globe.

Over the head of the westernmost twin in Figure 65 reads the label *raʾs al-tawʾam al-muqaddam* (the head of the foremost twin), referring to the first star, the one in the forehead [α *Geminorum*, Castor]. The star in the face of the eastern twin is labeled *raʾs al-tawʾam al-muʾakhkhar* (the head of the rear twin), the second star of the constellation [β *Gem*, Pollux]. Only these two stars are labeled on the Smithsonian globe; both labels reflect the Ptolemaic constellation image.

The more common traditional Bedouin designation for the two stars taken together was *al-dhirāᶜ* (the foreleg), which refers to the pre-Islamic concept of a lion covering a large part of the heavens. When the two stars are given this name they are generally considered as the seventh lunar mansion, for which reason this name appears on the ecliptic as the seventh lunar mansion at the division of the House of Gemini and the House of Cancer (the summer solstice) (see discussion of Lunar Mansion 7 for various interpretations of *dhirāᶜ*). On all globes examined, except those by the Lahore family and the two earliest (Nos. 1 and 34), which have very few star names, the stars in the heads of the twins are labeled with the Bedouin term *al-dhirāᶜ* rather than with Ptolemaic labels. Moreover, on all the globes except the two earliest and the Mughal ones, the stars in the two feet of the eastern twin [nos. 17, 18; γξ *Gem*] were labeled *al-hanᶜah.* This term is also the name of the sixth lunar mansion and gave rise to the "modern" name for the star γ *Gem*, Alhena. On the Smithsonian globe these two stars are not labeled in the constellation of Gemini, but the name appears as a lunar mansion along the ecliptic (see the discussion of Lunar Mansion 6).

Constellation 25. The Crab [Cancer]

FIGURE 66

In the Hellenistic world this constellation, the most inconspicuous of all zodiacal signs, was usually called καρκίνος (a crab), latinized as Cancer. Aratus (lines 892–908) calls it not only καρκίνος, but the manger or crib (φάτνη) between two asses (ὄνοι). This image of the crib and asses was common in later poetry. Theocritus (XXII, 21) says "the clouds disperse this way and that, the bears are seen again, and between the asses the dim crib, betokening that all is fair for voyaging" ([trns.] Gow, 159; cf. Virgil *Georgics*, I,356, ff). Mythographers (Hyginus, II,23) said that Dionysus placed the two asses in the heavens for they had helped him flee across a swamp to a temple in order to restore his sanity. Another story (Erat. *Catast.*, 11) says that the two asses brayed so loudly when Zeus was fighting the Giants, that the Giants took flight and were defeated. The crab was explained (Hyginus, II,23) as being one which had snapped at the foot of Heracles (Hercules) from the swamp when he fought the Ler-
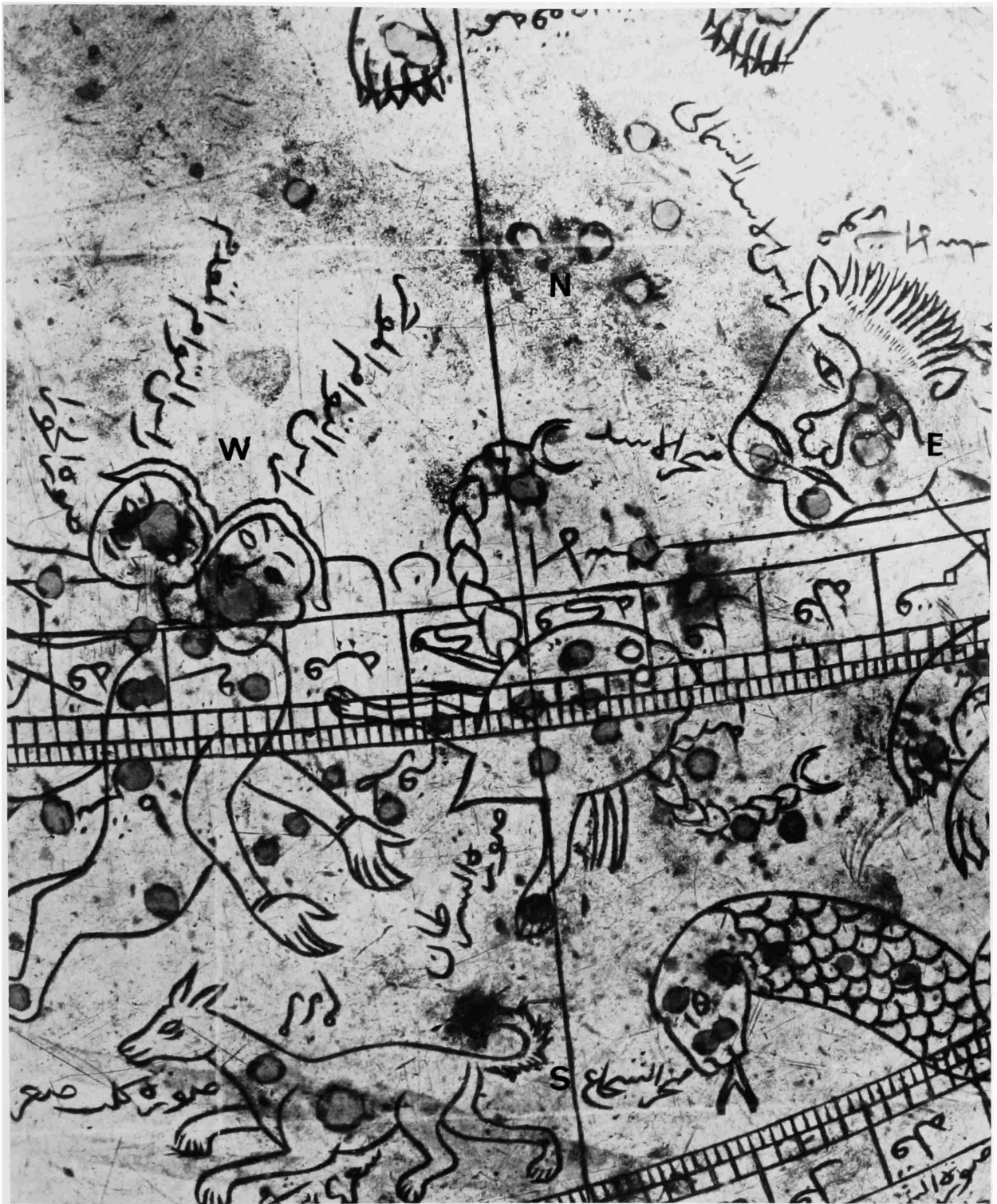
FIGURE 66.—The Crab [Cancer]. (Photo: Smithsonian no. 72-8589)

naean Hydra. Ptolemy named the constellation Cancer (*καρκίνος*) and noted that its first star was nebulous and called the crib (*φάτνη* latinized as Praesepe; see Gundel & Böker, col. 522 for Mesopotamian parallels).

In Arabic the constellation is called *al-saraṭān* (the crab). The inscription can be seen in Figure 66 behind the southern back leg. It is a fanciful representation, the back feet even having toes.

The line dividing the House of Cancer from the House of Leo passes through the constellation of the crab. Two lunar mansions are written on the south side of the ecliptic: one at the tail of Cancer, *ṭarf*, the ninth mansion marking 115¾° of the ecliptic; and *jabhah* the tenth lunar mansion, written next to the head of the crab at 128° along the ecliptic.

No stars in the constellation are named on the Smithsonian globe. The three stars in a row across the breast of the crab, however, frequently do bear names on other globes and in the astronomical literature, all derived from Greek concepts of the constellation. The middle star of these three (no. 1) is the open cluster [M44, Praesepe]. Al-Ṣūfī termed it *maʿlaf* (a manger, or stable) calling it *saḥābī* (cloudy). The two stars on either side of the Manger, nos. 4 and 5 of the constellation [*γδ Cancri*], were called by Aratus and Ptolemy "asses." Al-Ṣūfī also termed the two stars *al-ḥimārayn* (the two asses).

Alongside this terminology of Greek origin, however, al-Ṣūfī also presented a traditional Bedouin system of terms. In this system the open cluster Praesepe was called *al-nathrah* (the cartilage of the nose), and as such was the name of the eighth lunar mansion (see subsection discussion of Lunar Mansion 8 for related terms). This name arose also from the Bedouin conception of the lion, larger than the Ptolemaic Leo, in that part of the heavens. On the Smithsonian globe the term *nathrah* appears not in the constellation of Cancer, but in the zodiacal House of Cancer along the ecliptic as a lunar mansion. In the Bedouin tradition the open cluster Praesepe was also called *al-lahāh* (the uvula [of the lion]).

In keeping with the image of the large lion, the two unformed stars in front of and slightly above the head of the crab, nos. 3 and 4 of the unformed stars, were traditionally called *al-ṭarf* (the glance of the eyes [of the lion]; [*νξ Cancri*]). *Al-ṭarf* constitutes the ninth lunar mansion, and as such is written, not alongside the two stars, but in the House of Cancer along the ecliptic immediately behind the crab. Al-Ṣūfī (*Ṣuwar*, 173) adds that the Arabs called the first unformed star (above the southern claw), along with a small one behind *al-ṭarf, al-ashfār* (the places where the eyelashes grow).

The constellation consists of nine formed stars and four unformed ones, the latter being the two above the head and the two near the southern claw. It is assumed that the position of the star touching the northern claw is an error of the artisan and that it was intended to be a formed star.

Constellation 26. The Lion [Leo]

FIGURE 67

Aratus (lines 148–155) associated the Lion (*λέων*) with the sun's hottest path. Greek mythographers said that Leo was the Nemean lion killed by Heracles during his first labor. In the Arabic world the constellation was called *ṣūrat al-asad* (the constellation of the lion), written in Figure 67 above the head. A larger lion was seen in this region of the sky in the Bedouin tradition, only part of which overlaps with the Ptolemaic Leo. The constellation of Leo occupies the area between 130° and 170° of the ecliptic, its head in the House of Leo and its rear half in the House of Virgo. Three lunar mansions are found along the ecliptic: at 141½° between the front paws is *zubrah*, Lunar Mansion 11; at 154¼° under the belly is *ṣarfah*, Lunar Mansion 12; and at 167¼° on the right back paw is *ʿawāʾ*, Lunar Mansion 13.

The star on the mouth farthest from the ecliptic is labeled *mankhar al-asad* (the nose of the lion [no. 1; *κ Leonis*]). The star between the eyes is labeled *raʾs al-asad al-shamālī* (the northern
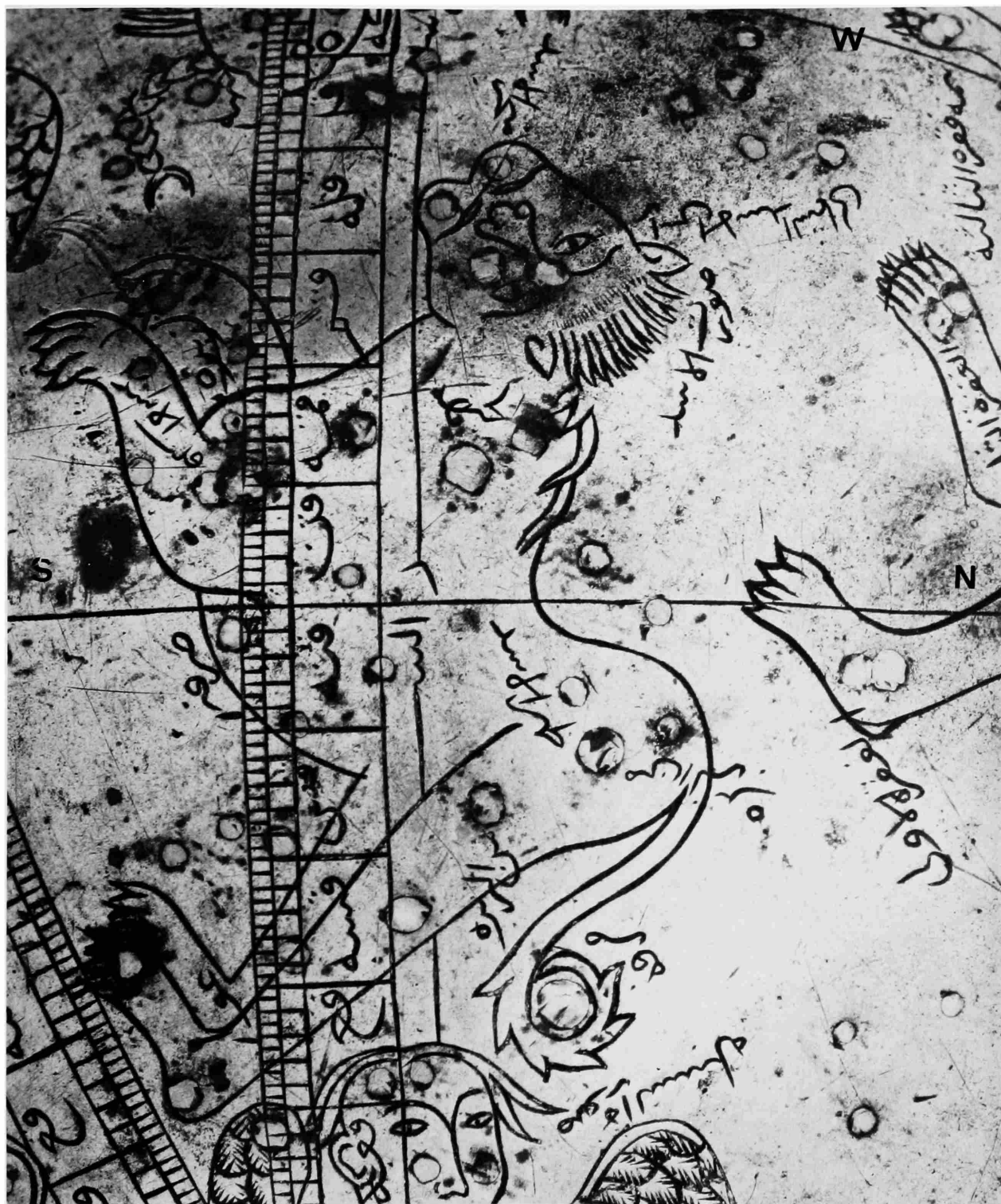
FIGURE 67.—The Lion [Leo]. (Photo: Smithsonian no. 73-2658)

head of the lion [no. 3; μ *Leo*]). The very large star of the two contiguous ones on the upper part of the lower forearm is termed *qalb al-asad* (the heart of the lion [no. 8; α *Leo*]). This first magnitude star was also called *al-malikī*(the royal one) from Ptolemy's term βασιλίσκος (a little king), hence its modern name Regulus. The large star on the rump is labeled *ẓahr al-asad* (the back of the lion [no. 20; δ *Leo*]). All of these star names reflect the Greek leonine outline transposed over the larger Arab one. The latter star [δ *Leo*] bears an additional title in Figure 67: *min al-zubrah* (one of *al-zubrah*). The name is written again at the star on top of the thigh, southeast of the other [no. 22; θ *Leo*]. These names indicate the two stars that represent the mane of the larger lion, *al-zubrah* meaning a mane. These stars gave their name also to Lunar Mansion 11.

Near two stars on the shoulders (nos. 5 and 6) of Leo in Figure 67 there is written *al-jabhah* (the forehead), which in the Bedouin tradition referred not only to these two stars but also to the one to the southwest (no. 9) and the very large one further south (Regulus). These stars [ζ γ η α *Leo*] were collectively called "the forehead [of the large lion]" and formed Lunar Mansion 10. The modern name of γ *Leonis*, Algeiba, is derived from the Arabic word for forehead. The word *jabhah*, representing the lunar mansion, is also written at 128½° of the ecliptic.

The star in the tail, no. 27, is labeled *ṣarfah* (change of weather [β *Leo*]). Since *ṣarfah* constituted Lunar Mansion 12, this same word is written again as a mansion at 154¼° of the ecliptic (see section on Lunar Mansions for further discussion).

The constellation of Leo consists of 27 formed stars and 8 unformed ones. The latter are the two over the back of Leo, the three under the belly and in front of the hind legs, and the three above the tail between Leo and Virgo and Ursa Major. These last three, over the tail (nos. 6–8 of the unformed stars), constitute the asterism called by Ptolemy πλόκαμος, known in Latin as Coma Berenices (Berenice's Hair). The asterism Coma Berenices was identified and named by the court astronomer to Ptolemy Euergetes in Alexandria, named Conon of Samos (see Bulwer-Thomas). He was a close friend of Archimedes and named the asterism in honor of Ptolemy's consort Berenice, who had vowed to dedicate a lock of her hair in a temple if her husband returned victorious from the Third Syrian War, which began in 246 BC. Ptolemy III did return, and the court astronomer preferred to place the lock of hair in the skies. Mythographers and poets wrote of the story (e.g., Hyginus, II,24; Callimachus 80–85, no. 110; Catullus, 66). The astronomer Ptolemy, however, refers to it only as a lock of hair, not mentioning Berenice. Al-Ṣūfī says that these three stars, which resemble a right triangle [αβπ *Comae Berenices*], were called by Ptolemy *al-ḍafīrah*, "a lock of hair" (cf. Kunitzsch [1974], 281–283). Al-Ṣūfī (*Ṣuwar*, 181–182) states that they are all of fifth magnitude and around them are many stars whose counting is difficult because of their compactness, which resembles the thickness of the Pleiades. The Bedouin image was of these stars forming the tail tuft on the tail of the enormous lion, for as al-Ṣūfī states (*Ṣuwar*, 182):

> These stars, together with the small close ones outside the three, are called *al-hulbah* (the coarse hair), and that is because outside *al-ṣarfah* (the star in Leo's tail) is a bent row of stars . . . so they liken these stars to the tail and the bright star at the root of the tail [i.e. *ṣarfah*] to the scrotum; and they compare the three which we have mentioned, with the nearby small ones in their midst, to the hair which is at the extremity of the tail. . . . The common people call these stars together "the ripe grain of wheat" (*al-sunbulah*), and many of the followers of the *anwāʾ* reckon that for these stars the House of Virgo is called *al-sunbulah* because they resemble that through their compactness and their large number.

The stars of Coma are unlabeled on the Smithsonian globe; on Nos. 4 and 5 they are encircled by a decorative device which Virgo holds, as if they were intended to go with Virgo rather than Leo.

Constellation 27. The Ear of Wheat [Virgo]

FIGURE 68

In Hellenistic times this constellation was described as a maiden, παρθένος (Virgo in Latin), with wings, holding in her hand an ear of wheat,

FIGURE 68.—The Ear of Wheat [Virgo]. (Photo: Smithsonian no. 72-3115)

στάχυς (*spica* in Latin). Aratus (lines 96–137) adds that she was also called δίκη (Justice) and dwelt on earth until the coming of the Bronze Age when she ascended to the heavens. In her role as Justice she was later associated with the Scales (Libra). The association of an ear of wheat with a maiden was also a symbol of the harvest, and indeed the autumnal equinox occurs in this sign. The northernmost star of the northern wing (above the bend of the elbow) was called προτρυγητήρ (that which rises before the vintage) by Aratus and Ptolemy (in Latin Vindemiatrix, the modern name of ε *Virginis*). Mythographers associated various figures with the maiden, including Demeter (because of the wheat) and Erigone, daughter of Icarus. The Arabic translation of παρθένος was *al-ᶜadhrā*ᵓ (the maiden), but the Bedouin name for the region soon replaced it in the literature. Thus *al-sunbulah* (the ear of wheat), probably of ancient Sumerian origin, became the standard name for the constellation and the zodiacal house, as can be seen on all extant globes, as well as in Figure 68 where *ṣūrat al-sunbulah* (the constellation of the ear of wheat) is engraved over the figure's northern wing.

Al-Bīrūnī (*Astrol.*, sec. 159) describes the Ptolemaic figure as "in the form of a maid with two wings, in a flowing skirt and in her hand an ear or two of wheat directed to the bottom of her skirt." On all the globes that were examined the constellation is depicted with wings, with her northern arm extending toward Boötes, but without an ear of wheat in her lower hand. On globes No. 4 and No. 5 the figure holds a swatch of hair or a decorative device incorporating the three stars of Coma in her northern hand. The three stars of Coma are visible in Figure 68 above her northern hand. The line separating the House of Virgo from the House of Libra passes across the shoulders of Virgo. This is the point of the autumnal equinox, and consequently the equator is shown to intersect the ecliptic. On Virgo's northern shoulder at the autumnal equinox is the word *simāk*, the name of the fourteenth lunar mansion. On her hip at 193° of the ecliptic, the word *ghafr* is engraved, and near the hemline at 205¾° is *zubānā*, the names of the fifteenth and sixteenth lunar mansions, respectively. See the section on Lunar Mansions for further details.

The very large star in the southern hand is the only star named in Figure 68, and it is α *Vir*, the fifteenth most brilliant star in the heavens, which bears the modern name Spica from the Latin rendering of the Greek word for an ear of wheat. In the Arabic translation of Ptolemy's *Almagest* στάχυς was translated by the word *al-sunbulah*, but the Bedouin word for the star soon dominated. In Figure 68 the star is labeled *simāk aᶜazal* (an unarmed *simāk*). The name *simāk* is of ancient possibly Babylonian origin and its meaning has been obscured with time (see Hommel, 596). In the Bedouin tradition this *simāk* represents one of the hind legs of the very large lion. The other hind leg of the lion was formed by the other star bearing the name *simāk*, Arcturus (*al-simāk al-rāmiḥ*), which can be seen in a direct line due north of Spica, at the hemline of Boötes. Of the star called *simāk* in Virgo, al-Ṣūfī (*Ṣuwar*, 193) says:

> They call it *al-aᶜzal* (unarmed) because it is opposite *al-simāk al-rāmiḥ* which is called *rāmiḥ* (armed) because the lance (*rumḥ*) is on its right; and these are two bright stars [both called *simāk*], one of which is near the foot of the Howler [Boötes], whom they call the ox-driver, and the other one is in the zodiac and is called "unarmed" because there is no weapon accompanying it.

The "unarmed *simāk*" in Virgo gave its name to the fourteenth lunar mansion.

The large star in the northern wing was called in Greek "the vintager" (in Latin, *Vindemiatrix*), but bears no traditional Bedouin name and seems not to have been as important to Bedouin imagery.

Five stars forming roughly a 90° angle (beginning with the star in the south wing, the one on the southern shoulder, the one at the side of the waist near the ecliptic, the large one in the middle of the waist, and the large one on the northern wing) formed the thirteenth lunar mansion, and collectively [βηγδε *Vir*] were called *al-ᶜawwā*ᵓ. On the Smithsonian globe the name appears only as a lunar mansion along the ecliptic. The star in the southern foot, together with the two at the hemline [nos. 22, 23, 25; ικλ *Vir*] were tradition-

ally called *al-ghafr* and comprised the fifteenth lunar mansion. The stars themselves are not labeled on the Smithsonian globe, although they frequently are labeled on other globes. The constellation of Virgo is composed of 26 formed stars and six unformed ones. The latter are the three along the southern arm (in the large graduated portion of the ecliptic) and the three south of the southern hand on the other side of the ecliptic along the outstretched writing giving the name of the House of Libra.

Constellation 28. The Balance [Libra]

FIGURES 69, 70

In Greek times, as in much earlier Sumerian times, the constellation now known as Libra was seen as the two claws of the scorpion, with Scorpio and Libra combined essentially into one constellation (see Gundel & Böker, cols. 522–529, 534; Hommel, 597). Thus both Aratus (lines 90, 438) and Ptolemy use the word χηλαί (claws) for the constellation. The concept of the asterism as a balance or scales (ζυγός), which was a later introduction, calls to mind the equality of day and night at the autumnal equinox, which occurs at the break between the House of Virgo and the House of Libra (see Brown 1:71; Gleadow, 169). Hyginus (II,26) states "this sign is divided into two parts on account of the great spread of the claws. One part of it our writers have called the Balance. But the whole constellation together was put in the sky, it is said, for the following reasons" [trns] Grant). He then recounts that Orion boasted he could kill anything on earth. Earth, angered at this, sent the Scorpion, which is said to have killed him. Zeus then placed Scorpio in the heavens as a lesson to men not to be too self-confident. Artemis, who had suffered an insult from Orion, requested Zeus that it be placed so that when Scorpio rises, Orion sets.

The name of the constellation translated into Arabic as *al-zubānā*, an old word of Sumerian origin meaning "the claws," and also, using a more recent word, as *al-mīzān*, or "the balance" (see Kunitzsch [1974], 191). Figure 69 shows the relation of the balance to the other constellations on a globe made in 998 H/AD 1589–1590 by ᶜAlī Kashmīrī ibn Luqmān (No. 10; for details of the set of scales depicted on the Smithsonian globe see Figure 70). On the Smithsonian globe the name of the constellation is *ṣūrat al-mīzān* (the constellation of the balance). Al-Ṣūfī (*Ṣuwar*, 199) says that he has seen globes on which this constellation was depicted as a man holding a small pair of scales that had no stars in it, and in fact on globe No. 1 the constellation is drawn in a similar manner, with all the stars (both formed and unformed) drawn within the form of the man, but for one near and two inside the small scale.

On the Smithsonian globe the constellation of Libra is drawn within the House of Scorpio, taking up about 222° to 235° along the ecliptic. At 218¾° of the ecliptic, the name of Lunar Mansion 17, *iklīl*, is written in the southern foot of the balance (see discussion of Lunar Mansion 17 for the five interpretations of this lunar mansion, four of which refer to stars in Libra and one to stars in Scorpio. Between the two parts of the balance, at 231½°, the eighteenth lunar mansion (*qalb*) is written. On the upper foot of Serpentarius there is written *shawlah*, the nineteenth lunar mansion at 244° of the ecliptic, and on the other foot *naᶜāʾim* at 257° of the ecliptic, the twentieth lunar mansion.

The names of stars in Libra on the Smithsonian globe all reflect the Greek tradition. The large star in the pan to the north (no. 3), is labeled *kiffah shamālī* (the northern plate of the balance [β *Librae*]). The large star on the other pan (no. 1) is termed *kiffah janūbī* (the southern plate of the balance [$\alpha^{1,2}$ *Librae*]). These two stars together make up the sixteenth lunar mansion called *al-zubānā* (the two claws [of the scorpion]). This lunar mansion name reflects the more ancient, probably Sumerian concept of the larger Scorpion, of which this constellation formed the claws. The name *zubānā* on the Smithsonian globe, however, is written only as a lunar mansion along the ecliptic and not as a star name.

Libra is composed of eight formed stars and nine unformed ones. The latter group consists of the pair, one on either side of the lines suspending the northern pan, the pair on either side
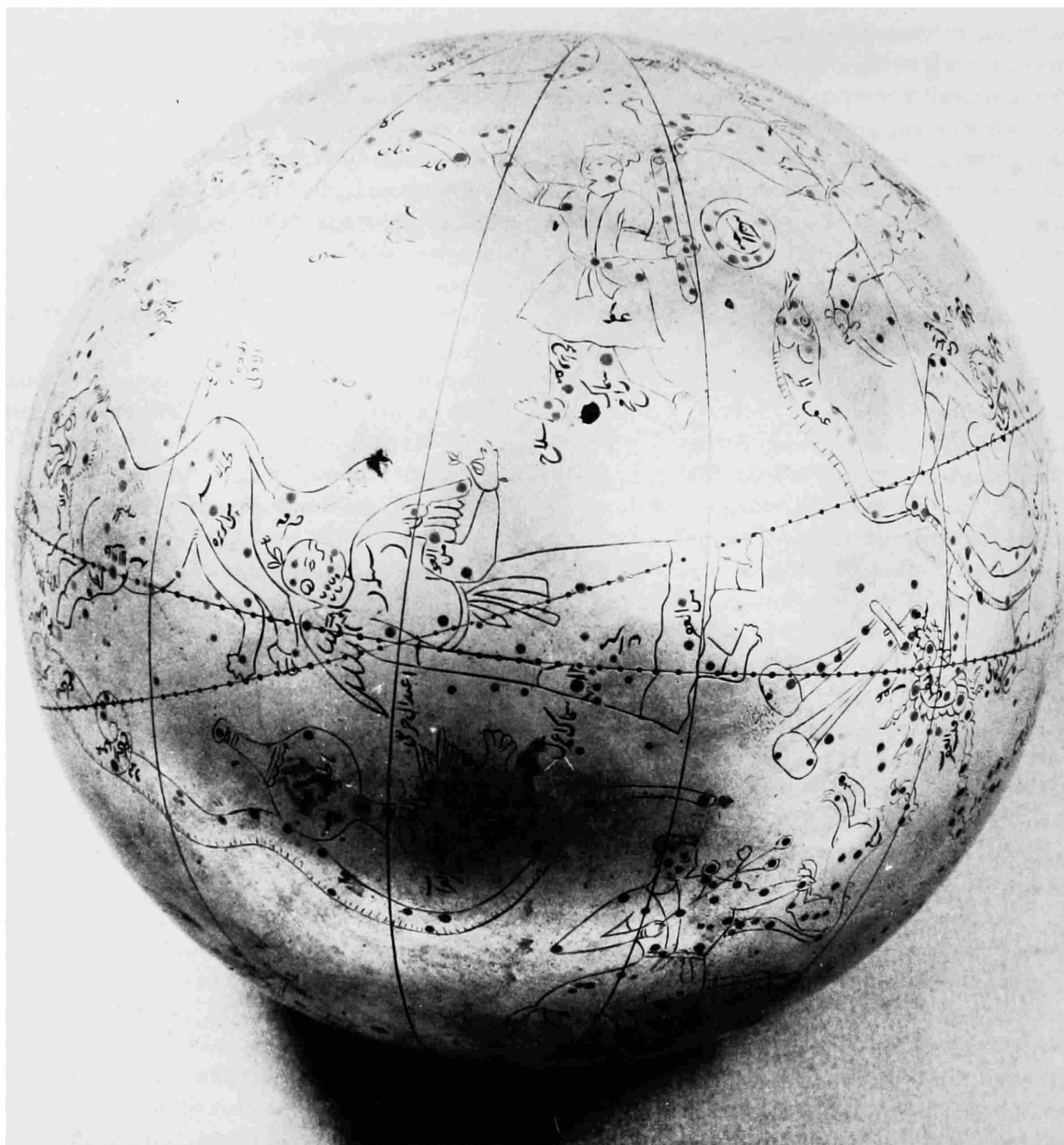
FIGURE 69.—The Balance [Libra]. Illustrated on an overall view of Globe No. 10, dated 998 H/AD 1589–1590, by ᶜAlī Kashmīrī ibn Lūqmān. London, private collection. (Photo: Alain Brieux)

of the northern claw of Scorpio, one in front of the mouth of Scorpio, one at the suspensory device, the pair, one on either side of the southern claw of Scorpio, and the large star to the south of Libra. The star above the bar holding the scales and to the south is an extra star (marked by an arrow in Figure 70) inadvertently added by the maker.

Constellation 29. The Scorpion [Scorpio]

FIGURE 70

In ancient Mesopotamia a large scorpion in this region of the heavens was apparently associated with the darkness which comes on as the year approaches the winter solstice, and it is one of the most frequently depicted zodiacal signs extant in Babylonian remains (see Gundel & Böker, cols. 522–528, 696). In Greek literature it was called σκορπίος. The Ptolemaic Scorpio in the star catalog covers a smaller area than the original scorpion asterism of Sumerian origin, for the constellation Libra was formed from part of the larger scorpion (see discussion of The Balance [Libra]). The mythographers associated with it the legend of the scorpion sent by Artemis to kill Orion (Hyginus, II, 26 and II, 34; Erat. *Catast.*, 7 and 32; Ovid *Fasti*, V,535–544). The Greek word for scorpion was translated by the common Arabic word *ᶜaqrab*, also meaning scorpion, as evidenced in the title of the constellation written in Figure 70 near the base of the tail, *ṣūrat al-ᶜaqrab* (the constellation of the scorpion). Al-Ṣūfī (*Ṣuwar*, 207) says it is a famous (*mashhūrah*) constellation.

In Figure 70 the scorpion covers about 235° to 265° of the ecliptic, its head being in the House of Scorpio and most of its body and tail in the House of Sagittarius. On the Smithsonian globe the constellation is composed of 20 formed stars and three unformed ones, the latter being the one near the end of the tail and the two below the lower foot of Serpentarius. The stars in the foot of Serpentarius who is stepping on the top of the Scorpion are counted with Serpentarius and not with Scorpio. Ptolemy, al-Ṣūfī, and Ulugh Bēg all catalog 21 formed stars in Scorpio. The inexplicably missing star on the Smithsonian globe should be located immediately to the north of the third star of the tail, counting from the base of the tail. This missing star, no. 14 in the catalogs, is part of a visual double [ζ^1 *Scorpii*], no. 15 next to it being ζ^2 *Sco*. Curiously no. 13 of the constellation (the second star of the tail) is also a visual double, $\mu^{1,2}$ *Sco*, but is counted as only one star in the catalogs. The first unformed star, near the end of the tail, was said to be nebulous (*saḥābī*). This is an open cluster visible to the naked eye [OC 6475; M7].

Only one star in Figure 70 appears to be labeled. Near the last star in the body, in small writing, is written *al-ᶜaqrab* (the scorpion). One would naturally apply this to the nearest star, no. 9 of the constellation [τ *Sco*]. I can find no evidence, however, on any globes nor in al-Ṣūfī or Ulugh Bēg for the use of this name with this star. On the other hand, the middle of the three stars near the mouth, no. 1, was later called *al-ᶜaqrab*, from which the modern name Akrab arose [β *Sco*]. It is unlikely, however, that the maker would write the title at such a distance from the star. The maker probably intended it to go with the second star from the end of the body, no. 8, which was called *qalb al-ᶜaqrab* (the heart of the scorpion [α *Sco*]) and simply omitted the *qalb*. On globe No. 11, quite certainly by the same maker who produced the Smithsonian globe, *qalb al-ᶜaqrab* is clearly written near the eighth star of the constellation. The "heart of the scorpion" was the traditional Arab name given the bright red star called by Ptolemy ἀντάρης (*Antares*), which is used as the name of the star today (cf. Kunitzsch [1974], 291–292). The name Antares comes from ἀντὶ (similar to) Ἄρης (Mars)—that is, similar in color to the planet Mars (Ideler, 181). In the Bedouin tradition the two stars on either side of the "heart of the scorpion" [nos. 7, 9; $\sigma\tau$ *Sco*] were called *al-niyāṭ* (the artery) for the aorta (see al-Ṣūfī, *Ṣuwar*, 209; Kunitzsch [1961], no. 205). The "heart of the scorpion" (Antares) along with Vega, "the falling eagle" were together called *al-harrārān* "the two whimpering [dogs]" who howl because of the cold that usually sets in with the rising of these two stars [α *Sco* and α *Lyrae*; see Kunitzsch [1961], no. 116a]. The "heart of the scorpion" also gave its name to the eighteenth lunar mansion and as such is written on the Smithsonian globe simply as *qalb* at 231½° of the ecliptic.

The two stars on the tip of the tail, nos. 20 and 21, were called *al-shawlah* (the raised tail [of the scorpion]) and formed the nineteenth lunar
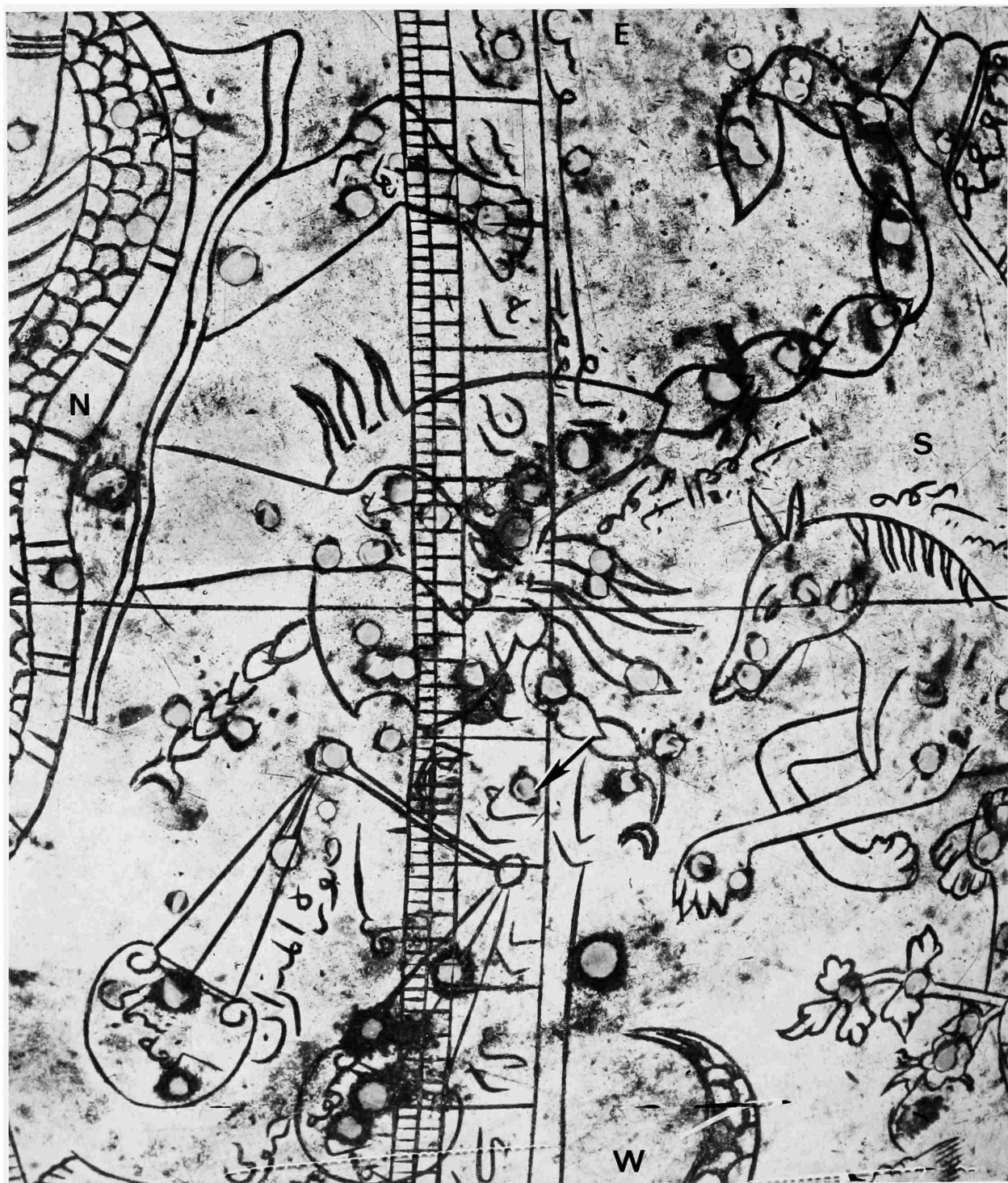
FIGURE 70.—The Scorpion [Scorpio]. (Photo: Smithsonian no. 72-3114)

mansion [λυ *Sco*]. The stars themselves in Figure 70 are not labeled, but the word *shawlah* as a lunar mansion appears at 244° of the ecliptic. The modern name of λ *Sco* is Shaula (see the section on Lunar Mansions).

Constellation 30. The Archer, that is, the Bowman [Sagittarius]

FIGURE 71

In Greek literature the Archer, *τοξότης*, was frequently represented as a centaur, although this is not mentioned by Aratus (lines 301–307), who says merely that when the sun scorches the bow (*τόξον*) and the archer (*τοξευτής*) it is a time of storm; the sailor should not sail at night but put into shore in the evening. This is one of the zodiacal signs that is probably of Babylonian origin (see Gundel & Böker, cols. 522–528). The Babylonian archer was depicted with wings, which in Greek times became a mantle or cloak. In Islamicate representations of the Ptolemaic constellation, there is usually a fluttering end of a head band or band of a turban, as in Figure 71 (see Wellesz [1959], 10), while al-Bīrūnī (*Astrol.*, sec. 159) says he has long tresses. The mythographers (Erat. *Catast.*, 28; Hyginus, II,27) noted that while some called it a Centaur others did not because centaurs did not use arrows. The legend given was that he was Crotus, son of Euphene, nurse of the Muses. He was very clever in the arts, for which reason the Muses requested Zeus to represent him in a star group. Zeus added the arrow to represent his keenness.

In the indigenous Arab image for this region, deriving from the common Sumerian origin, a bow without a person was seen. The traditional Arab name was *al-qaws* (the bow), which gradually replaced the translation of the Ptolemaic name for the constellation and the related zodiacal house. Thus on the Smithsonian globe the zodical house is labeled *al-qaws* (the bow). The title of the constellation on the Smithsonian globe, written in front of the head, reflects the Arabic translation of the Ptolemaic title as well: *ṣūrat rāmī al-qawwās.* This should be amended to *ṣūrat al-rāmī wa huwa al-qawwās* (the constellation of the archer, i.e., the bowman). In Figure 71 the arm holding the arrow is drawn so that it covers all but the arrowhead. Most of the constellation, which occupies the area from 265° to 300° of the ecliptic, is in the House of Capricorn, though the bow is in the House of Sagittarius.

Three lunar mansions are written along the ecliptic in Figure 71: *baldah*, the twenty-first, at 270° or the summer solstice (the name is written at the bow); *dhābiḥ*, the twenty-second, at 282¾°, behind the neck of the archer; and *bulaᶜ*, the twenty-third, at 295¾°, in front of the head of Capricorn.

The archer is composed of 31 formed stars. The small star behind the elbow of the Archer [no. 19; $h^{1,2}$ *Sagittarii*] has incorrrectly been placed outside the outlines of Sagittarius by the maker of this globe. In addition, the large star on the elbow [no. 18; $\chi^{1,2}$ *Sgr*] is misplaced, for it ought to be more to the north; moreover, it has been indicated by a large silver dot when in fact it was considered to be only of fifth magnitude.

In Figure 71 the star in the eye is labeled *ᶜayn al-rāmī* (the eye of the archer) and was considered nebulous [no. 8; $\nu^{1,2}$ *Sgr*]. The star near the hoof of the lower front leg is labeled *ᶜurqūb al-rāmī* (the archer's tendon) [no. 23; $\beta^{1,2}$ *Sgr*]. Al-Ṣūfī (*Ṣuwar*, 217–218) says this important star was placed on astrolabes even though it is less than fourth magnitude, correcting Ptolemy's magnitude of two. The star on the knee of the same leg, no. 24, is labeled *rukbat al-rāmī* (the archer's knee [α *Sgr*]); al-Ṣūfī also corrects its magnitude. There is written near the star in the arrowhead the word *qaws* (bow). It is unlikely this term was intended to apply to this star [no. 1; γ *Sgr*], for such a term is not found on any globes nor in texts. Star no. 1 was occasionally referred to as *zujj al-nushshābah* (the arrowhead of a wooden arrow) or *zujj al-sahm* (al-Ṣūfī, *Ṣuwar*, figure 30; Kunitzsch [1974], 294), also meaning arrowhead. It is possible the maker simply intended it as a general label for stars in the bow (although in the literature only the six stars in the eye and ribbon were called the bow; Al-Ṣūfī *Ṣuwar*, 220),

FIGURE 71.—The Archer, that is, the Bowman [Sagittarius]. (Photo: Smithsonian no. 72-3112)

or that he intended it to apply to the star at the southern tip of the bow [no. 3; ε *Sgr*] whose common name today is Kaus Aust.

The Milky Way is very rich in this area and affected the traditional Bedouin terminology, which is reflected in the names of the lunar mansions derived from this constellation. Two groups of four stars each were seen as ostriches,

four arriving at the river (the Milky Way) and four leaving. The twentieth lunar mansion was named for ostriches (*naᶜāʾim*; see discussion of Lunar Mansion 20 for details as to which stars in Sagittarius made up the ostriches).

Six stars (nos. 9–14) in a curve, consisting of the three in the face (excepting the nebulous one in the eye) and the first three of the fluttering band, were called by al-Ṣūfī *al-qalāʾis* (the young ostriches) as well as *al-qilādah* (the necklace [ξ^2οπdρυ *Sgr*]). The area under the fluttering headband was called *al-baldah* (the place) and was said to contain no stars. *Baldah* gave its name to the twenty-first lunar mansion.

Constellation 31. The Goat [Capricornus]

FIGURE 72

The tenth zodiacal sign, Capricorn, is also unquestionably of Babylonian origin (see Gundel & Böker, cols. 522–528). It was seen originally as a sea-goat, most often drawn with the tail of a fish. In Greek it was called αἰγόκερως, a horned goat, and according to one Greek legend was the Cretan goat-nymph named Amaltheia who reared Zeus in the cave of Dicte on the Aegean Hill (Neugebauer OCD). Others (Hyginus, II, 28; Erat. *Catast.*, 27) say it was Aegipan (αἰγίπαν) who had cared for Zeus. He was said to have frightened the Titans by his braying. The lower part of his body is shaped as a fish since he hurled shellfish, instead of stones, against his enemy. Mythographers also said he was Pan whom Egyptian priests had said threw himself into a river thereby making the lower part of his body a fish while the rest of his body remained a goat. In this way he escaped the monster Typhon, and Zeus, admiring his cunning, placed him among the constellations.

In the Islamic world he was called *al-jadī* (the goat), a name which he bears in the title written at the end of his horns in Figure 72 and also as the title of the House of Capricorn along the ecliptic. Al-Bīrūnī (*Astrol.*, sec. 159) criticized the use of this word for the constellation since it literally means a kid or young goat, suggesting instead the word *tays* (adult male goat). Nonetheless, the former is the usual title of the constellation. In Figure 72 Capricorn is drawn with no hind legs, as is customary, but his fish tail is not distinct. In the manuscripts of al-Ṣūfī and on most globes he is drawn clearly with a fish or mermaid-like tail that is a faithful reproduction of the classical form, except for globe No. 1 (the earliest), on which it is depicted as having four legs and resembling a deer.

The constellation of Capricorn occupies the area between 295° and 327° of the ecliptic, with its head in the House of Capricorn and its body in the House of Aquarius, the line dividing the two Houses passing through its cheek and forward front leg. Three lunar mansions can be seen in Figure 72: the twenty-third, *bulaᶜ*, at 295¾° and in front of Capricorn's head; *suᶜūd*, the twenty-fourth mansion, at 308° and in the neck of the sea-goat; and on the rump at 321¼° of the ecliptic, *akhbiyah*, the twenty-fifth lunar mansion.

No stars are labeled on the constellation on the Smithsonian globe. Capricorn is comprised of 28 formed stars.

Two stars in its head, the one at the base of the inside horn and the larger one below the three on the horns, nos. 1 and 3, both considered of less than third magnitude although they are represented by different sizes of plugs on the Smithsonian globe, gave their names to the twenty-second lunar mansion. These two [$\alpha^{1,2}\beta$ *Capricorni*] were called *saᶜd al-dhābiḥ*, the meaning of which, as with all the *saᶜd* lunar mansions, has become so obscure with time that it is virtually impossible to translate it. A very rough translation might be "the omen of sacrifice." The word *dhābiḥ* is engraved on the Smithsonian globe as a lunar mansion along the ecliptic at 282¾° beside the neck of the constellation Sagittarius in the House of Capricorn (see Lunar Mansion 22 for a discussion of *saᶜd* stars). According to al-Ṣūfī (*Ṣuwar*, 227) the Bedouins also called the lowest of the three stars at the base of the horns "the sheep (*shāt*) which is slaughtered" [no. 2; ν *Capricorni*].

FIGURE 72.—The Goat [Capricornus]. (Photo: Smithsonian no. 72-3116)

The two brightest stars in the body of Capricorn, the two large ones very close together as if a double star in the middle of the hind quarters (nos. 23 and 24) were frequently labeled on globes, in fact on all except the two earliest globes (Nos. 1 and 34), on No. 26, and on the present globe, the latter two from the Lahore workshop. These two stars [γδ *Cap*] were called *sa^c^d nāshirah*, which translates roughly as "omen of fertility." The brightest of the two, considered to be of third magnitude (the one closest to the tail; δ *Cap*), was called *dhanab al-jadī* (the tail of the goat), a name it bore on astrolabes and on some class B globes such as that made in 1065 H/AD 1655 by Ḥāmid ibn Muḥammad Muqīm of the Lahore workshop (No. 68).

Constellation 32. The Water-Pourer [Aquarius]

FIGURE 73

This zodiacal constellation is called by Aratus ὑδροχόος (the water-pourer), of which he says (lines 282–298) that when the sun is in him "the sailor should avoid the open sea, for fierce are the south winds then and hard the frost." Later mythographers (Hyginus, II, 29) identified him with Deucalion (who reigned when the great flood took place) or Ganymede (cupbearer to the gods), but the simple "water-pourer" is retained in the Ptolemaic catalog. In the Ptolemaic constellation the flow of water streams into the mouth of another constellation, Piscis Austrinus. Figure 73 presents an overall view, while Figure 87 shows Aquarius in detail. On the Smithsonian globe the water-pourer is one of four bearded figures, and the title of the constellation is written to the left of the head as *ṣūrat sākib al-mā^ᵓ^* (the form of the pourer of water), the same title used by al-Ṣūfī (*Ṣuwar*, 231) who goes on to say *wa huwa al-dalw* (that is to say, the bucket). The word *al-dalw* (the bucket) represents the indigenous Bedouin image of the area, which derived from a Sumerian source shared with the Greek imagery. The traditional term *dalw* replaced the Arabic translation of the Ptolemaic name as a title for the House of Aquarius. Thus *al-dalw* is the title for the House on the Smithsonian globe, while the constellation bears the Ptolemaic title.

The figure occupies the space along the ecliptic of about 328° to 345° with one arm stretched backward over Capricorn to about 305°. The division of the House of Aquarius from the House of Pisces passes through the eastern arm and lower leg of the constellation of Aquarius. Two lunar mansions can be read along the ecliptic: at 321° *akhbīyah*, the twenty-fifth at the rear of Capricorn; and at 334½° *muqaddam*, the twenty-sixth mansion, which is between the skirt and the stream of water. On the Smithsonian globe the constellation contains 41 formed stars. According to all the star catalogs it should contain 42 formed stars. The star that the maker of the Smithsonian globe inadvertently omitted should have been located in the stream of water just below the vessel, and is no. 23 in the listings [κ *Aquarii* (?) or Flam. 78 (?)]. Three unformed stars were also considered part of the constellation. These can be seen near the second bend of the stream of water, between the water and the tip of the tail of the sea-monster Cetus. One of the three stars, directly below the two that lie close together is so tarnished it is difficult to make it out; these three stars are today considered a part of the constellation Cetus.

The only star labeled on the Smithsonian globe is the large one at the end of the stream of water, in the mouth of the Southern Fish. This star, α *Piscis Austrini*, was considered by all catalogs at that time to be no. 42 of the constellation of Aquarius, although today it is numbered as part of the constellation of the Southern Fish. The star is labeled *fam al-ḥūt* (mouth of the fish) from which arises the modern term Fomalhaut for this star, the eighteenth brightest in the heavens. Al-Ṣūfī (*Ṣuwar*, 239) stated that this star was in the Bedouin tradition also called *al-ẓalīm* (the male ostrich), adding that "the bright star which is in the end of the river (Eridanus) is also called that; and I have seen on some globes the word *al-ẓalīm* inscribed between these two stars." The image of the ostriches is in keeping with those seen in Sagittarius. Another traditional name for Fom-
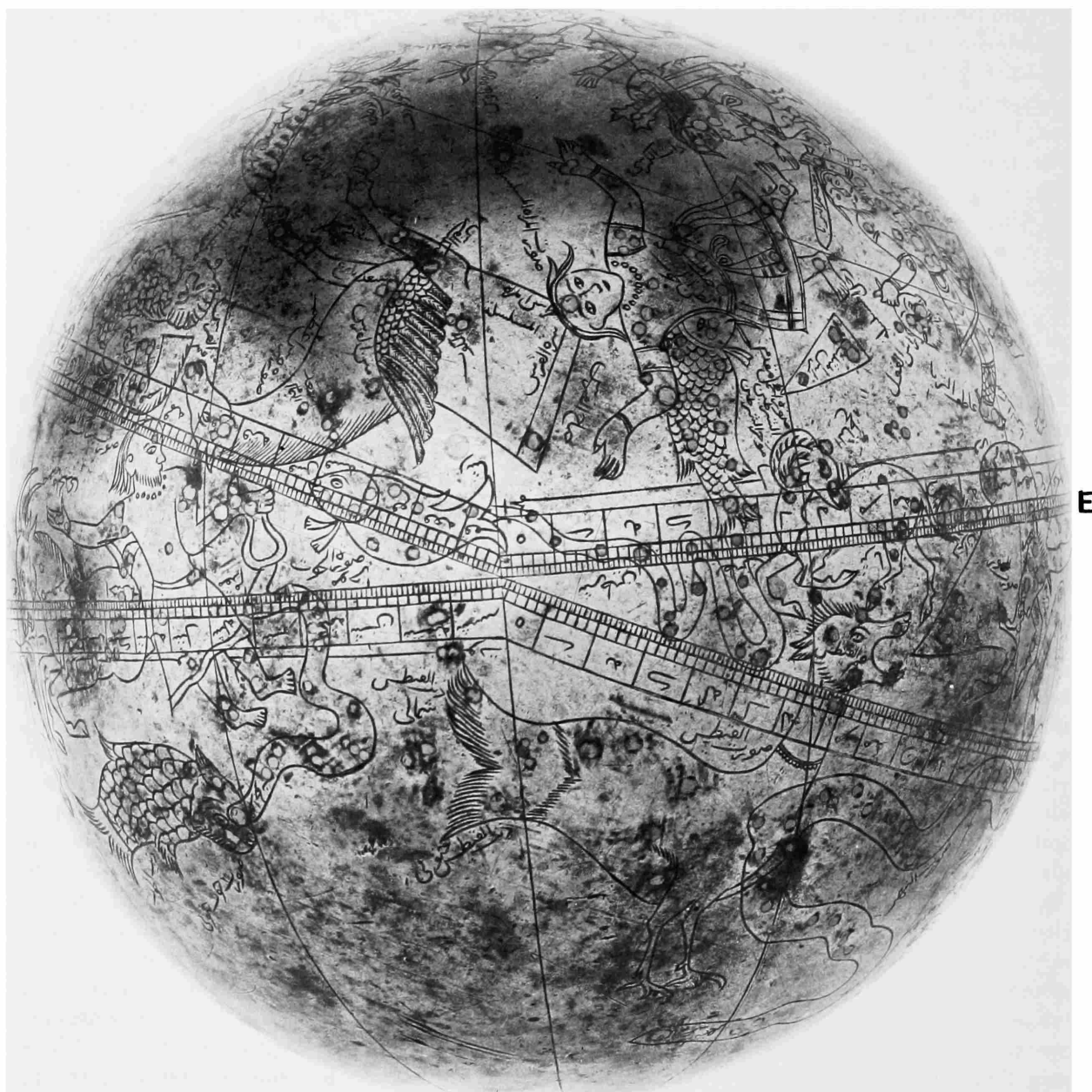
FIGURE 73.—The Water-Pourer [Aquarius] is on the left side of the globe. See also Figure 87. This view shows the area around the vernal equinox. (Photo: Smithsonian no. 72-3084)

alhaut was *al-ḍafda*^{c} *al-awwal* (the first frog), because as Al-Ṣūfī (*Ṣuwar*, 239) said, the bright star in the tail of Cetus [β *Ceti*] was called "the second frog." These latter two stars were also singled out by Aratus (lines 395–398), though he did not call them frogs.

The four stars on the hand and wrist of Aquarius, holding the water jug, made up the twenty-fifth lunar mansion called *sa*^{c}*d al-akhbīyah* [nos. 9–12; $\gamma\pi\zeta\eta$ *Aqr*]. On the Smithsonian globe the term *akhbīyah* is written as a lunar mansion along the ecliptic. These four stars form the modern

asterism of the Y of Aquarius, also called The Water Jar. The twenty-fourth lunar mansion was derived from the two stars on the western shoulder of the Water-Pourer, nos. 4 and 5 [$\beta\xi$ *Aqr*] and no. 28 of Capricorn in the end of its tail, and as such was called *saᶜd al-suᶜud*, which translates roughly as "omen of good fortune." The three stars in the hand over Capricorn, nos. 6–8, comprise the twenty-third lunar mansion [Flam. 7 and $\mu\varepsilon$ *Aqr*] called *saᶜd bulaᶜ*. The two stars on the eastern shoulder of Aquarius, nos. 2 and 3, were frequently called *saᶜd al-malik*, roughly translated as "the royal omen" [αo *Aqr*], a title frequently used for these stars (see globes Nos. 3 and 5; see section on Lunar Mansions for a discussion of the *saᶜd*-stars).

Constellation 33. The Fish [Pisces]

FIGURE 74

Again the concept of water dominates this area of the zodiac as it had with the preceding sign, Aquarius. The fishes, ἰχθύες, Aratus says (lines 239–247; [trns.] Mair, p. 227) are placed one higher, more to the north, than the other and thus it

louder hears the fresh rush of the north wind. From both there stretch, as it were, chains (δεσμά), whereby their tails on either side are joined. The meeting chains are knit by a single beautiful and great star, which is called the Knot of the Tails. Let the left shoulder of Andromeda be the guide to the northern Fish, for it is very near.

Mythographers (Hyginus, II,30; Manilius, IV, 519–581) relate the story that Venus and her son Cupid came to the river Euphrates in Syria where the monster Typhon appeared. They both threw themselves into the river and became fishes. For this reason the Syrians stopped eating fish for fear they would seem to oppose the protection of the gods and so they would not catch the gods themselves.

The drawing of the constellation on the Smithsonian globe is another faithful rendering of the classical form. The fishes are drawn in a playful manner, especially the one nearest the water poured by Aquarius and the neck of Pegasus, which even has an eyebrow; they both appear to have small ties about their necks. The division of the House of Pisces from that of the House of Aries (the vernal equinox) passes behind the tail of the western fish in figure 74. The western fish actually lies on the equator, which in Figure 74 is coming from the lower left and continues to the upper right. The graduations of both the ecliptic and equator begin their numbering at the vernal equinox, but the numbering of the celestial equator was repeated after the autumnal equinox. Consequently the western fish lies along the equator graduated from 160° to 180°, north of the section of the ecliptic graduated 340° to 360°. The band and the eastern fish pass through the first 30° of the ecliptic. Four lunar mansions can be seen: at 347¼° between the water poured by Aquarius and the western fish is *muᵓakhkhar*, the twenty-seventh mansion; at the vernal equinox by the tip of the tail of the western fish is *rishāᵓ*, the twenty-eighth. At 13° of the ecliptic near the first turn of the connecting band there reads *sharaṭayn*, the first lunar mansion, and at 25½°, *buṭayn*, the second mansion.

The constellation bears the title *ṣūrat al-ḥūt* (the constellation of the fish), engraved under the head of the western fish. This is the common title for both the constellation and zodiacal house and is the traditional Bedouin term for the region which replaced the term *al-samakatān* (the two fish), which had been used to translate the Ptolemaic title. Clearly the Bedouin image was of *one* large fish in this area, no doubt deriving from a Babylonian image which was also the source for the two fishes of the Greek world. According to the star catalogs the constellation consists of 34 formed stars. In Figure 74, 35 stars can be seen, there being for some unknown reason an extra star in the band connecting the fish, in the second twist of the band from the eastern fish (indicated by an arrow). The star at the end of the tail of the eastern fish (near Andromeda) is usually placed in the band; the spacing of several stars is not very precise. The star at Andromeda's underarm is to be counted with Pisces. The constellation also has four unformed stars, two of which are in the ecliptic beneath the western fish and two just south of the ecliptic near the tip of
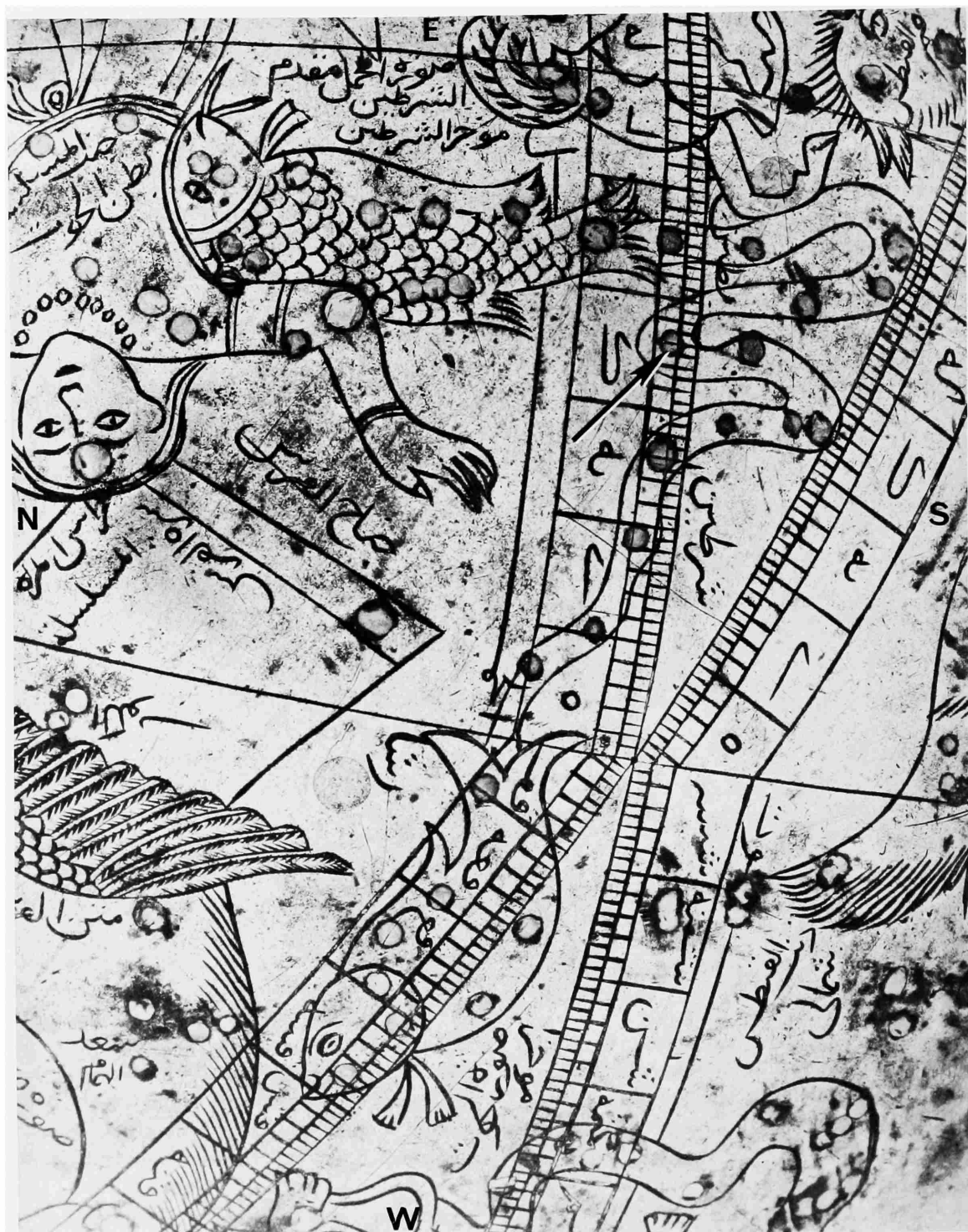
FIGURE 74.—The Fish [Pisces]. (Photo: Smithsonian no. 72-3113)

the tail of Cetus which can be seen in the lower righthand corner of Figure 74.

No star in Pisces is labeled on the Smithsonian globe. There is written across the chest of Andromeda *baṭn al-ḥūt* (the belly of the fish). This term refers to the star on Andromeda's waist closest to Pisces [*β Andromedae*], and arose from a Bedouin conception of a large fish lying across the area of Andromeda. This star gives its name to the twenty-eighth lunar mansion, and as such was also called in the *anwāʾ* tradition *al-rishāʾ* (the rope). The latter term represents the lunar mansion on the Smithsonian globe, written at the vernal equinox. The prominent star mentioned by Aratus as the Knot of the Tails is probably the third in the band between the fishes, counting from the eastern fish. This star [no. 19; *α Piscium*] was called by al-Ṣūfī (*Ṣuwar*, 252) *ᶜaqd al-khayṭayn* (the knot of the two ties) from the Ptolemaic image. Though it is the brightest star of the constellation, it does not seem to have had as important a role in Bedouin terminology, for it bears no traditional Arab name and is not labeled on any globes. The modern name for the star is El Rischa, from the name of Lunar Mansion 28. Arab astronomers and writers of *anwāʾ* literature, however, did not use this term for *α Piscium*, but only for *β Andromedae*, where it does not mean a knot, but a rope, arising from the conception of a bucket in nearby Pegasus.

Constellation 34. *Qīṭus* [Cetus]

FIGURE 75

The southern constellations (those south of the ecliptic) represent for the most part signs of darkness, evil spirits, and toil that populate the vast ocean or deep into which the heavenly bodies sink and through which sailors must struggle. The first southern constellation was called by Aratus (lines 354–359) "the mighty sea-monster," "the hated sea-monster," and "the dark-blue Cetus," Cetus being the Latin transliteration of the Greek κῆτος. Aristotle (*PA*, 669a) used the word for any animal of the whale kind, "whales, the dolphin and all spouting cetacea (ἀναφυσῶντα κήτη)." Mythographers (e.g., Hyginus, II,31) associated the sea-monster with the monster sent by Poseidon to kill Andromeda. The constellations of Andromeda and Perseus who saved her are due north of the constellation Cetus, whose head is just south of the Ram, Aries. Thus his head is north of the equator.

In the Islamic world the Ptolemaic constellation was called *al-qīṭus*, a transliteration of the Greek name. In the Greek world the constellation was most frequently seen as a whale, while in the Islamic world it was often depicted like a "senmurvs," an oriental winged dragon, and almost always shown wearing a collar (Wellesz [1959], 18). In Figure 75 it has a snarling dog's head, bird's feet, and a feathered fish tail, producing an effect more fantastic than sinister. The constellation consists of 22 formed stars, including the one in the hair, next to the leg of Aries, and also the four on the chest, which are shared with the River (Eridanus). The star names in Figure 75 all reflect the Ptolemaic schema. The large star in the jaw is labeled *fam al-qīṭus* (the mouth of Cetus [no. 3; *γ Ceti*]). The star on the northern tip of the tail, closest to the equator, is called *dhanab al-qīṭus shamālī* (the northern tail of Cetus [no. 21; *ι Cet*]). The title of the star on the southern part of the tail is *dhanab al-qīṭus janūbī* (the southern tail of Cetus [no. 22; *β Cet*]). One name often given to the latter star today is Deneb Kaitos, derived from this Arabic title.

Another modern name given the latter star today, Diphda, comes from the Arabic name given the star in the Bedouin tradition: *al-ḍafdaᶜ al-thānī* (the second frog). The first frog is the large star in the mouth of the Southern Fish [*α Piscis Austrini*; Fomalhaut], which is west of Cetus. These two stars were also singled out by Aratus (lines 395–398), though he did not call them frogs.

In keeping with the notion of ostriches in the area of the Southern Fish and Sagittarius, the stars nos. 12–16 (the five in the trunk of Cetus τυζθη *Cet*] were traditionally called *al-naᶜām* and *al-naᶜāmāt*, both meaning ostriches (Kunitzsch
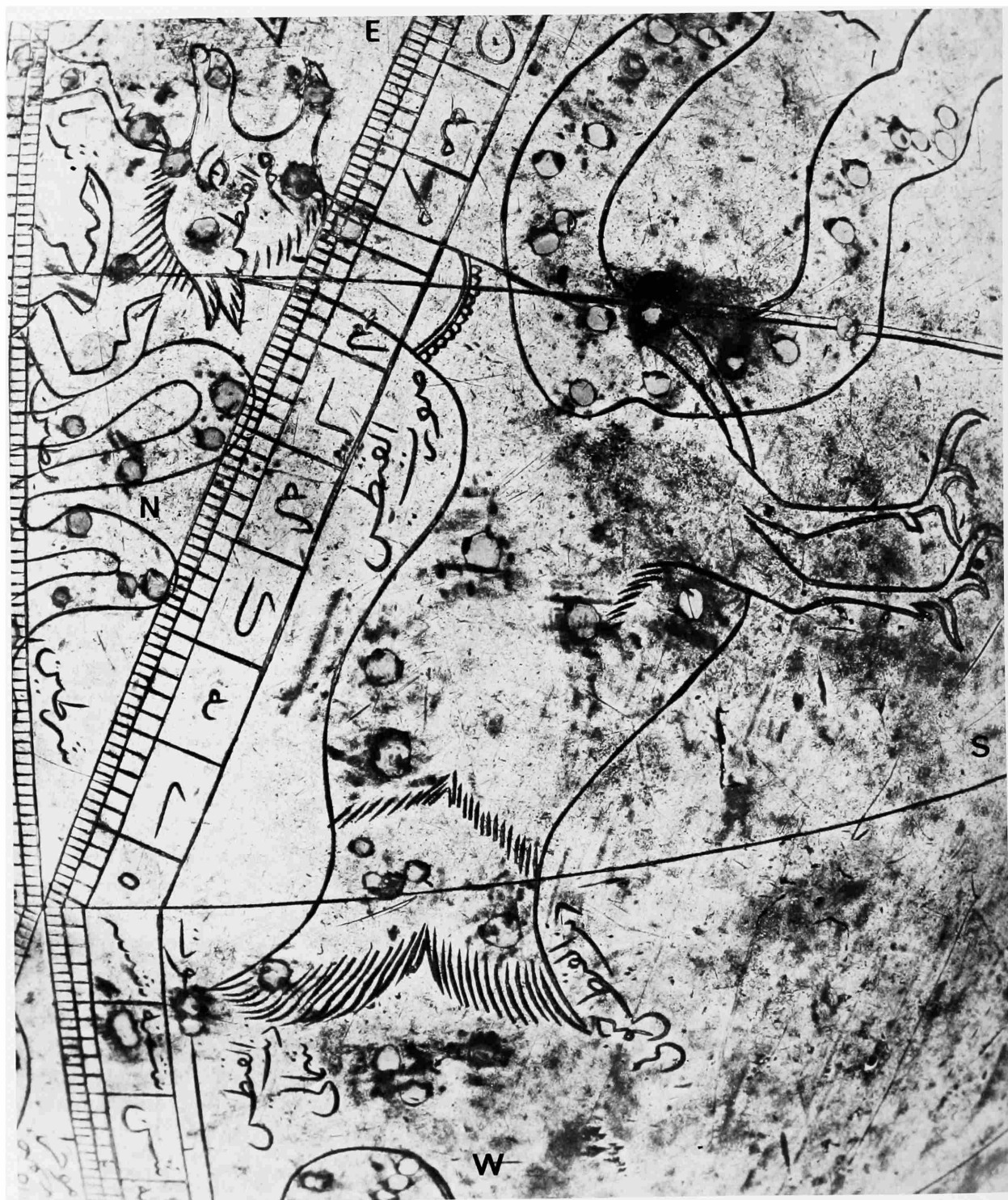
FIGURE 75.—Qīṭus [Cetus]. (Photo: Smithsonian no. 72-3101)

[1961], nos. 181, 184). While not marked on the Smithsonian globe, these stars are labeled in this manner on globes Nos. 3, 4, and 5.

In the Bedouin tradition, the first six stars of the constellation [λαγδξμ *Cet*], in the head and the neck, not including the one in the hair, were collectively called *al-kaff al-jadhmā*ᵓ (the cut-off hand [of *al-thurayyā*]). This group of stars was seen as part of the human form of which the Pleiades (called *al-thurayyā*) formed the center (see the discussion of Lunar Mansion 3 for details on this early asterism).

The four on the chest, shared with the River Eridanus, were called *baṭn* (the belly [nos. 8–11; ρσεπ *Cet*]). On globes No. 1 and No. 34, the two earliest, they bear this label. The four stars that are close together in the root of the tail [nos. 17–20;φ^2, 0.198,φ^1, 0.161 *Cet*] al-Ṣūfī (*Ṣuwar*, 269) remarks he has seen labeled on some globes as *al-niẓām* (the string of pearls), but that he has not been able to find that in any of the literature. (Kunitzsch [1961], no. 206 says the engraver of the globe seen by al-Ṣūfī simply made an error and meant to inscribe *al-naᶜām* or "ostriches.") Al-Ṣūfī also adds that it has been said that the set of stars forming Cetus was called *al-baqar* (the cows), but that is said by Arabs "who have no knowledge of the stars" (see Kunitzsch [1961], no. 58a).

Although the names of Bedouin origin do not appear on the Smithsonian globe, they do all appear on one or another of the globes prior to the seventeenth century, with the exception of "the string of pearls" and "the cows," which occur on none of the globes examined.

Constellation 35. The Giant [Orion]

FIGURES 76, 78

The second southern constellation is Orion, who for the most part lies north of the celestial equator. The equator passes through the three stars forming the well-known belt of Orion. Orion was one of the five star groups named by Homer and was perhaps the first constellation to which a Greek legend was assigned. Traditionally he was a great hunter, eventually killed by Artemis, according to Homer (*Od.*, V, 121–124), or as another tradition has it, by a scorpion (Scorpio) sent by her. Aratus (lines 323–325) does not describe the figure of Orion (ὠρίων), but merely says "Let none who pass him spread out on high on a cloudless night imagine that, gazing on the heavens, one shall see other stars more fair" ([trns.] Mair, 233). Ptolemy described him as he was usually depicted in Greek art: holding in his right hand a λαγωβόλον, a staff for flinging at hares (although also used for a shepherd's staff or crook); a short bent sword or dagger (μάχαιρα) hung from his waist; and a lion's skin (δορά) was draped over his left arm. He was also depicted as kneeling in a manner similar to Hercules (see Figure 54).

Al-Ṣūfī (*Ṣuwar*, 264) describes the constellation as "resembling somewhat the form of a man having a head, two upper-arms and two feet; and he is called *al-jabbār* (the giant) because he has two thrones [a reference to groups of stars in Lepus and Eridanus] and in his hand there is a stick and around his middle a sword." He uses simply the word *al-ᶜaṣā* to translate λαγωβόλον in the descriptive text, but does amplify it further in the catalog, calling it *al-ᶜaṣā dhāt al-kilāb* (a stick used for [wild] dogs). On the Smithsonian globe it is difficult to tell what the weapon is intended to be. The most radical change that al-Ṣūfī made was to describe in the text the nine stars that, according to Ptolemy, were on the lion's skin as being on a sleeve, *kumm*. Thereafter in the Islamic world Orion was drawn with an elongated sleeve on his left arm, with the exception of globe No. 1, where he appears to hold some long object in his left hand, which contains nine stars. Surprisingly, in his catalog al-Ṣūfī does not mention the sleeve, but adhers strictly to the *Almagest*, stating that the nine stars are "in the skin (*al-jild*) worn on the left arm."

In Figure 76 Orion can be seen between and below Taurus and Gemini (for a detailed view see Figure 78). The constellation is titled under the eastern arm *ṣūrat al-jabbār* (the constellation of the giant). The traditional Bedouin term for
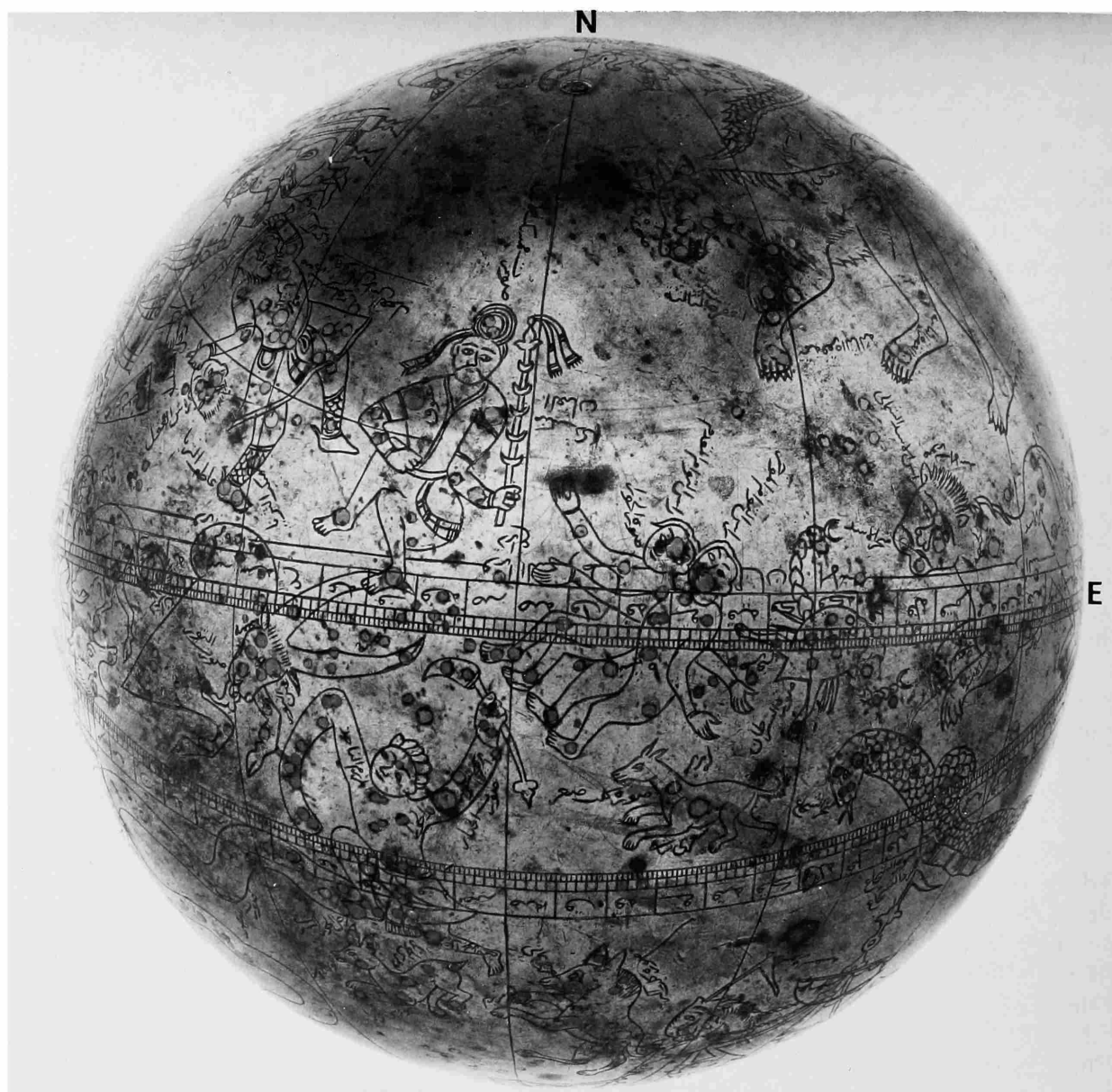
FIGURE 76.—The Giant [Orion] (see also Figure 78). This view also shows the area around the summer solstice. (Photo: Smithsonian no. 72-3079)

the region was *al-jawzā*ᵓ, which comes from a root meaning "to marry"; its precise meaning is obscure and the word may have arisen through a complex philological error (Kunitzsch [1961], 24; Ideler, 214–218). In any case the word *jawzā*ᵓ seems to have referred to a large, possibly feminine, figure (see section on Classical Greek and Pre-Islamic Sources, for a discussion of this Bedouin image). The name *al-jawzā*ᵓ appears as the title of the constellation of Orion on the two earliest globes (Nos. 1 and 34) and is a component of many of the individual star names. On

the Smithsonian globe the name *al-jawzāʾ* is given to the constellation and House of Gemini, which was also in the area covered by the ancient *al-jawzāʾ*. The very large star on the eastern shoulder on the Smithsonian globe is given two names: *mankib al-jawzaʾ* (shoulder of *al-jawzāʾ*) and *yad al-jawzāʾ* (arm of *al-jawzāʾ*). The star referred to is no. 2 [α *Orionis*], a variable star that is the twelfth brightest star of the heavens. The modern name of the star, Betelgeuse, arose from another name for the star, not on the Smithsonian globe, *ibṭ al-jawzāʾ* (armpit of *al-jawzāʾ*)

The larger of the two stars next to each other on the west shoulder is labeled *al-mirzam* [no. 3; γ *Ori*, Belletrix]. The term *al-mirzam* is a traditional term applied to three stars in the heavens, apparently in the sense of companion, since in all three instances there is a larger star with which it is paired. This pairing is most evident in Canis Major and Canis Minor, where it is applied to companions of Sirius and Procyon (see section on Classical Greek and Pre-Islamic Sources). The use of *mirzam* for a star in Orion may be of later origin, and was not used consistently (Kunitzsch [1961], no. 166). Al-Ṣūfī (*Ṣuwar*, 269) says that some people called the bright red star [α *Ori*] by the name *mirzam al-jawzaʾ*, but that it is incorrect and that the term *mirzam* properly belongs to the third star of the constellation [γ *Ori*] which precedes the brighter star, like the two *mirzams* of the two Sirii (a reference to Sirius and Procyon). This third star [γ *Ori*] is also labeled on the Smithsonian globe *al-nājidh* (? the fortunate one), another obscure Bedouin term.

The large star on the western foot of Orion, which is shared with the River Eridanus into which the figure is stepping, is labeled *rijl al-jawzāʾ al-yasrī* (the left foot of *al-jawzāʾ*). This star [no. 35; β *Ori*, Rigel] is the seventh brightest of the heavens; it was also called by al-Ṣūfī (*Ṣuwar*, 269) *rāʿī al-jawzāʾ* (the shepherd of *al-jawzāʾ*).

The star on the knee on which he is resting, no. 38, is termed *rijl al-jawzāʾ al-yamī* (the right foot of *al-jawzāʾ*). The modern name of the star, Saiph [κ *Ori*], is derived from the name given by al-Ṣūfī (*Ṣuwar*, 269) to the three stars [nos. 30–32; c $\theta^{1,2}\iota$ *Ori*] composing the dagger, *sayf al-jabbār* (the sword of the giant), a name clearly derived after the introduction of the Ptolemaic constellations. The Bedouin term for these three stars was *al-jawāzī* (Kunitzsch [1961], no. 105). Two of the stars, $\theta^{1,2}$ ι *Ori*, comprise the asterism known today as the Sword of Orion.

The three stars forming the famous asterism of the Belt of Orion, $\delta\epsilon\zeta$ *Ori*, were called in Greek χάριτες (the [three] Graces). In the Islamic world nos. 26–28 were called *minṭaqat al-jawzāʾ* and *niṭāq al-jawzāʾ*, both meaning "the belt of *al-jawzāʾ*." The former term is the one from which the modern name of δ *Ori*, Mintaku, is derived. These three stars were also (al-Ṣūfī *Ṣuwar*, 269) called *al-naẓm* and *al-niẓām* (a string of pearls) as well *faqār al-jawzāʾ* (the vertebrae of *al-jawzāʾ*). These stars are not labeled on the Smithsonian globe. The traditional Arabic terms for the nine stars on the elongated sleeve [$y^2 y^1 o^2 \pi^{1-6}$ *Ori*], nos. 17–25, were *tāj al-jawzāʾ* (the crown of *al-jawzāʾ*) and *dhawāʾib al-jawzāʾ* (the hanging locks of *al-jawzāʾ*). These imply a different positioning of the figure than that of the later Ptolemaic form. These titles do not appear on the Smithsonian globe.

The star marked on the head of Orion is given as no. 1 in the catalogs. Al-Ṣūfī (*Ṣuwar*, 264) says of it:

> The first star which is on the head is nebulous (*saḥābī*) but it is three small stars next to one another in the form of a small triangle. Ptolemy gave to the middle of the triangle the rank of a star and gave it longitude and latitude in the book [*Almagest*].

There is indeed luminosity in the area of these three stars [$\lambda\varphi^1\varphi^2$ *Ori*], which both Ptolemy and al-Ṣūfī called nebulous. Al-Ṣūfī in his catalog counted the three stars as one, following Ptolemy, and Ulugh Bēg maintained the same designation. On some globes (e.g., Nos. 4 and 5), three stars are indicated in the head instead of one as on the Smithsonian globe. The Bedouins traditionally called these three small stars *al-haqʿah*, the name of the fifth lunar mansion (see section on Lunar Mansions). Al-Ṣūfī adds that they also were called *al-athāfī* (the three-legged

support of a cooking pot) since they resembled it.

The constellation of Orion is comprised of 38 formed stars and no unformed stars. In Figure 78 what appears to be one star on the eastern side of the chest is actually two contiguous stars. They are not usually placed so close to one another. In the hand overhead there are only four stars and not five as appears at first glance. The great Nebula of Orion, M42, does not seem to have been recorded at this time.

Constellation 36. The River [Eridanus]

FIGURE 77

Aratus (lines 360–366) was the first to name this winding constellation that has the form of a river, speaking of the poor remains of Eridanus (*ἠριδανός*) as a river swollen with tears (*πολύκλαυτος ποταμός*). The legend referred to is that of the river Po, into which Phaëthon fell when struck by Zeus's thunderbolt and where his sisters the Heliades wept for him. The river Eridanus was partly burnt up, hence the "poor remains." Eudoxus had called it simply "river," and later writers associated it with the Rhone or the Rhine and even the Nile and Oceanus (Hyginus, II,32). The river twists from the forward foot of Orion over to Cetus the Sea-Monster, where it shares four stars; it turns toward Lepus the Hare and then back under the feet of Cetus. In Figure 77 the River has the appearance of a snake, biting at Orion's foot; actually Orion is supposed to be stepping into the River. A very large round plug on the globe can be seen across the southern segment of the river, indicated by arrows (see Chapter 2 for details regarding plugs).

In Arabic the constellation is titled *ṣūrat al-nahr* (the constellation of the river), written in Figure 77 at the first bend. The only star labeled in Figure 77 is the one at the end of the river, beneath the feet of Cetus. This star, no. 34, is labeled *akhir al-nahr* (the end of the river). This is *not* the star bearing today the name Achernar [*α Eridani*], the ninth brightest star of the heavens, for the latter star has a declination (measured from the equator) of −57°29′ while the star called *akhir al-nahr*, no. 34 of the constellation, has according to al-Ṣūfī a latitude of −53°30′ measured from the ecliptic. This last star of the constellation must be *θ Eridani*, a double star resolvable with binoculars, today called Acamar and having a declination of −40°31′ from the equator. Thus the classical constellation did not extend as far south as does the modern outline of the asterism.

The constellation is composed of 34 formed stars, not including the 4 shared with Cetus. There are no unformed stars. Al-Ṣūfī (*Ṣuwar*, 277–278) reports that in the Bedouin tradition the thirty-fourth star of the constellation was called *al-ẓalīm* (the male ostrich) and that between this ostrich and the ostrich at the mouth of the Southern Fish [*α Piscis Austrini*] are many stars called *al-riyāl*; which he further explains with the phrase *firākh al-naᶜām* (baby ostriches).

The Arabs traditionally called the first three stars of Eridanus (the three in the head [λβψ *Eri*]), along with no. 36 of Orion [*τ Orionis*] (the one above the very large one on the foot of Orion) *kursī al-jawzāᵓ al-muqaddam* (the anterior throne of *al-jawzāᵓ*) because, according to al-Ṣūfī (*Ṣuwar*, 277) they are in a square resembling a throne. The thirty-fifth star of Orion, also on the foot [*β Orionis*], was said to be alongside the square and resemble the foot (*rijl*) on the throne.

The Bedouins (al-Ṣūfī *Ṣuwar*, 277) also called nos. 14–20 of the River (the five stars to the south of the chest of Cetus plus the first two of those shared with Cetus) *udḥī al-naᶜām* (the hatching place in the sand of ostriches). Al-Ṣūfī expands his explanation: "that is to say, its nest and place of its eggs . . . those which are around these stars are called the eggs and the egg-shells" [$\zeta\rho^{2,3}\eta$, W.B.2^h788,τ^{1-5} *Eri* plus επ *Ceti*; cf. Kunitzsch [1961], no. 308]. Al-Ṣūfī further remarks (*Ṣuwar*, 278):

> I have seen in Shiraz many stars near the horizon resembling a skiff (*zawraq*) in which there is a bright star of third magnitude which, along with the one on the south branch of the tail of Cetus, i.e. the second frog, and the star in the mouth of the fish, is in a triangle. In the spaces are stars of
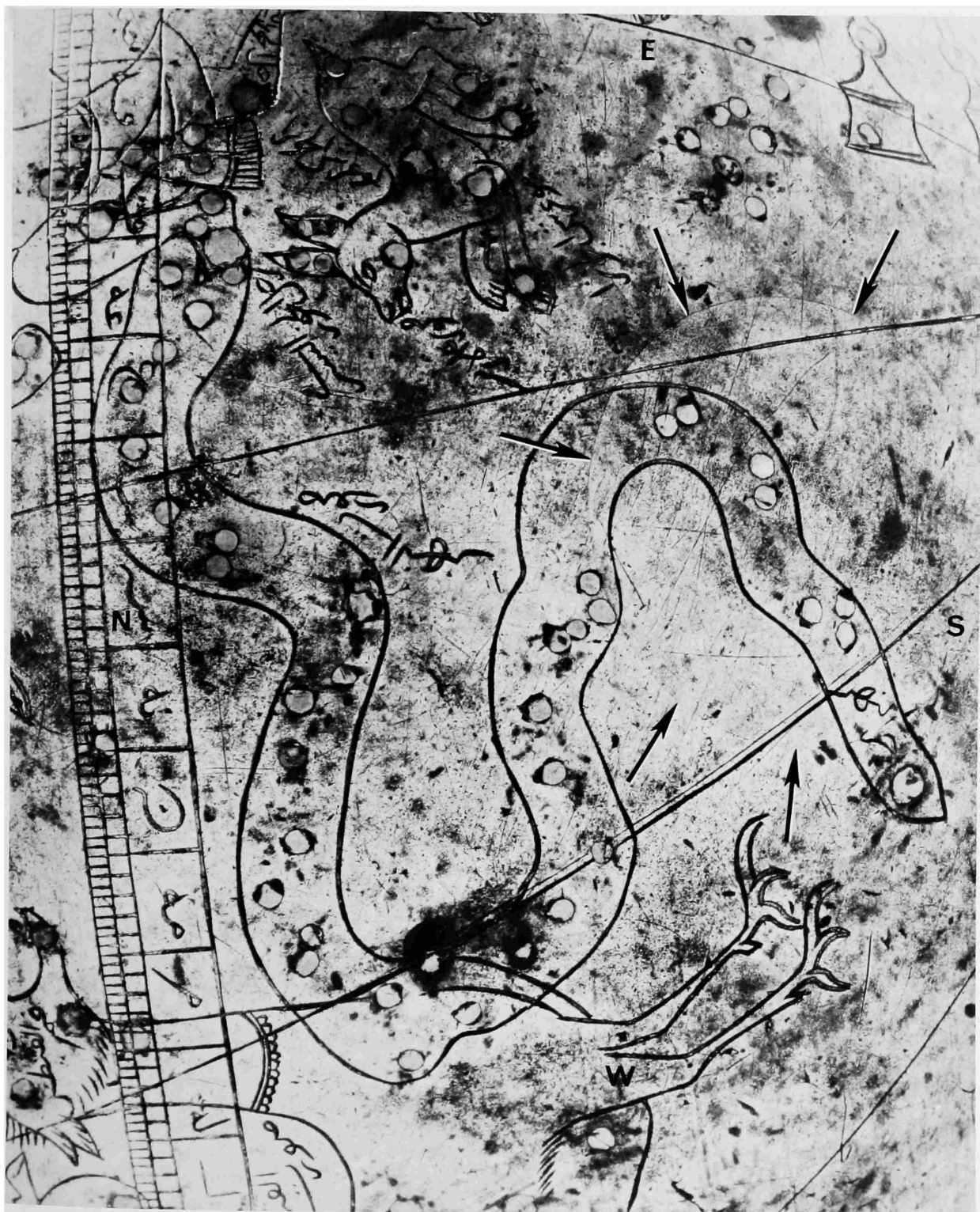
FIGURE 77.—The River [Eridanus]. Arrows indicate plugs. (Photo: Smithsonian no. 72-3110)

fourth, fifth, and sixth magnitudes, all of which are called *al-riyāl* (baby ostriches) of which nothing is said by Ptolemy.

Constellation 37. The Hare [Lepus]

FIGURE 78

Beneath the feet of Orion is the hare (λαγωός or λαγῶς in Greek), continually pursued by the hunter (Orion) and his dog (Sirius) which is to the east of Lepus (Aratus, line 338). The mythographers (Hyginus, II,33; Erat. *Catast.*, 34) said that Hermes placed the hare among the constellations because of its swiftness. Hyginus gives the account of the extreme multiplication of the hares on the Island of Leros, after which, he says, the constellation was placed in the heavens so men could remember "that nothing is so desirable in life but that later they might experience more grief than pleasure from it" (trns. Grant).

The Ptolemaic name of the constellation was translated literally into Arabic as *ṣūrat al-arnab* (the constellation of the hare). In Figure 78 the rabbit resembles a dog more than a hare. The expression *ᶜarsh al-jawzāᵓ* (the seat of *al-jawzāᵓ*) is written twice near the hare in Figure 78, once below and once above. These terms refer to four stars of Lepus, the two on the forepart of the body and the two on the hind feet, nos. 7–10. Al-Ṣūfī (*Ṣuwar*, 238) states that these four stars [*αβγδ Leporis*] were called *kursī al-jawzāᵓ al-muᵓakhkhar* and *ᶜarsh al-jawzāᵓ* (the posterior throne or seat of *al-jawzāᵓ*) "because they are in between the two legs of *al-jawzāᵓ* [a figure in roughly the area of Orion] in the location of the throne." The adjective "posterior" is used to distinguish this throne of *al-jawzāᵓ* from another one in the constellation of Eridanus. In Figure 78 the letters *m-w* are written before the expression *ᶜarsh al-jawzāᵓ* inscribed under Lepus. This is probably an abbreviation of *al-muᵓakhkhar* (the posterior). Similarly what looks like *l-w* before the same label engraved over the back must also be intended as the abbreviation *m-w*. The identical letters occur on globe No. 11, which was made by the same maker who produced the anonymous Smithsonian globe. Of these four stars al-Ṣūfī (*Ṣuwar*, 283) also adds "and I have read in some books of the *anwāᵓ* that they are called *al-nihāl*." The latter word means men or beasts (usually camels) going to drink water in order to quench their thirst, and from this name the "modern" name of the lower star in the forepart of the body, Nihal, (*β Leporis*), was derived. The modern name of the other star on the front shoulder, *α Leporis*, is Arneb or Alarneb, from the Arabic name for the constellation. The constellation is composed of 12 formed stars and no unformed ones.

Constellation 38. The Greater Dog [Canis Major]

FIGURE 79

The brightest star in this constellation, which is the brightest in all the sky, was mentioned by Homer (*Il*, V,5–6; XXII,26–30) and called by the name *σείριος* (the scorcher). The later Latin name was Sirius. It was said of the star that it was "a baleful sign (*κακὸν σῆμα*) for it brings to suffering mortals much fiery heat," for when it rises with the sun it marks the season of greatest heat. Homer mentioned also that it was the star men call the Dog of Orion. Hesiod (*Works and Days*, 584–588) speaks of Sirius when he says:

> In the exhausting season of summer; then is when goats are at their fattest, when the wine tastes best, women are most lascivious, but the men's strength fails them most, for the star Sirius shrivels them, knees and heads alike, and the skin is all dried out in the heat (trns. Lattimore, pp. 87, 89).

By the time of Aratus this star "that keenest of all blazes with a searing flame" (lines 330–331) was seen as part of a constellation and marked the jaw of the Dog, which was the faithful hound of the Hunter Orion. The star is still called the dog-star and the days of greatest heat the dog-days.

In the Islamic world the Ptolemaic constellation was called *al-kalb al-akbar* (the Greater Dog). Al-Ṣūfī (*Ṣuwar*, 285) says of it, "it is a constellation of a dog behind the constellation of *al-jawzāᵓ* (a figure in the area of Orion) and the constellation of the Hare, for which reason it is called

FIGURE 78.—The Hare [Lepus]. (Photo: Smithsonian no. 72-3107)

FIGURE 79.—The Greater Dog [Canis Major]. (Photo: Smithsonian no. 72-3108)

kalb al-jabbār (the dog of the giant, Orion). In his catalog, al-Ṣūfī says that the brilliant star in the jaw, Sirius, is called *al-kalb* (the dog), following Ptolemy. In his discourse on the constellation al-Ṣūfī (*Ṣuwar*, 288) presents the traditional Bedouin imagery for this region in which two *Sirii* were seen. The traditional Arabic word used for *α Canis Majoris* was *shiʿrà*, which apparently comes from a source, probably Babylonian, that it shared in common with the Greek term *σείριος* (see Hommel, 597–598, 619; Kunitzsch [1959], 117, 118, notes 1, 3). In Arabic the word has little meaning that seems appropriate, except perhaps as interpreted as "to have a distinctive mark," i.e. to be distinctive, or possibly shaggy, unkemp hair, which Drechsler (13) suggests could apply to the radiant appearance of Sirius (see section on Classical Greek and Pre-Islamic Sources for the traditional legend of the two *Sirii*, Sirius, the southern *shiʿrà*, and Procyon, the northern *shiʿrà* in the Lesser Dog, who were sisters of Canopus, *suhayl*, who had married *al-jawzāʾ*, and the related terminology). In Figure 79 Sirius is labeled *siʿrà yamānī*. This is no doubt an error (occurring also on globe No. 11), both in agreement of the adjective and diacritical points, and ought to read *shiʿrà yamānīyah* (the southern *shiʿrà*). The reading on the Smithsonian globe for this star is from the root *sʿr*, which means to burn or be in flames. Thus it appears to be more in alignment with the Greek *σείριος*, meaning "scorcher."

The large star on the upper front paw, no. 9, is labeled *mirzam* and is *β Canis Majoris* (Almirzam or Murzim). This is one of three stars on the globe bearing the label *mirzam*, used in the sense of companion, the other two being in Orion and Canis Minor (see section on Classical Greek and Pre-Islamic Sources).

Al-Ṣūfī (*Ṣuwar*, 289) presents some additional Bedouin star names for this region, which also antedate the introduction of Ptolemaic astronomy. The two stars on the rump, the one on the upper thigh, and the one on the tail [nos. 12,14,15,18; *o^2δεη CMa*] were together called *al-ʿadhārà* (the virgins) and also *ʿudhrat al-jawzāʾ* (the hymen of *al-jawzāʾ*), *al-jawzāʾ* being a large feminine figure seen in the area occupied by the Ptolemaic Orion. The Arabs also called the star on the end of the rear foot (no. 17) and all of the 10 nearby external stars except the two brightest (no. 9 and 10), *al-qurūd* (the baboons) and also *al-aghrub* (the crows; cf. Ideler, 248).

The constellation of Canis Major is comprised of 18 formed stars and 11 unformed ones. In Figure 79 there is one formed star missing (no. 8), which should be next to the small star on the leg immediately under the chin. Of the 11 unformed stars, 10 are to be seen below and to the southwest of the dog. The eleventh external star, actually no. 1 of the unformed stars in the catalogs, is north of the head of the dog on the other side of the equator at 105° along it, and lies between Canis Major and Canis Minor. The star cannot be seen in Figure 79, but is visible in Figure 80 of Canis Minor.

Constellation 39. The Lesser Dog [Canis Minor]

FIGURE 80

The constellation of Canis Minor consists of only two formed stars and is placed beneath Gemini and Cancer, which can be seen to the north. The dog lying north of the celestial equator, like the greater dog that is directly south of the equator, follows the constellation of Orion and was considered one of the hunter's companions. In the Homeric literature neither this constellation nor either of its stars is mentioned, while Aratus (line 450) refers only to the larger of the two stars, calling it *προκύων*, which shines brightly beneath the twins; the name literally means "before the dog" and refers to the fact that this star rises before the dog-star Sirius in Canis Major. The Greek word is the source of the modern name of the star Procyon. By the time of Ptolemy the star had, with the nearby star, become part of a recognized constellation, itself having the form of a dog.

In the Islamic world the constellation was commonly given the name *al-kalb al-aṣghar* (the lesser dog) from the Ptolemaic conception of the con-

FIGURE 80.—The Lesser Dog [Canis Minor]. (Photo: Smithsonian no. 72-8591)

stellation. In Figure 80 it is labeled in front of the figure *ṣūrat kalb ṣaghīr*, which is poor grammar for "the constellation of the small dog."

The Arabic terminology for the two stars reflects the earlier traditional Bedouin ideas of the heavens. The larger star, Procyon, the eighth brightest of the skys, is labeled in Figure 80 *si^cra shāmī*, which ought probably to be corrected to *al-shi^c rà al-shāmīyah* (the northern Sirius). Al-Ṣūfī (*Ṣuwar*, 293) says it is called "the northern" because it sets in the northern half. The "southern Sirius" is the Sirius of Canis Major (for a discussion of the meaning of the word *shi^crà* see Constellation 38, and for the legend of the two Sirii who were considered sisters of Canopus see the section on Classical Greek and Pre-Islamic Sources).

The smaller star in the neck of the dog is labeled *mirzam* [*β Canis Minoris*]. This is one of three stars termed *mirzam*, probably meaning companion, the other two being in Orion and Canis Major (see p. 117 for a discussion of how this term relates to the Bedouin legends given this region of the heavens).

Al-Ṣūfī (*Ṣuwar*, 293) adds that the Arabs called the two stars together *dhirā^c al-asad al-maqbūḍah* (the drawn up foreleg of the lion). He continues:

> And they call it *maqbūḍah* because of its remaining behind [rising after] the other forearm of the two stars which are along the head of the Twins; and it is in a line with the one on the shoulder of Orion [has the same celestial latitude].

He adds that many say the two stars form the seventh lunar mansion, but that actually the seventh lunar mansion is composed of the two stars on the head of Gemini (see the section on Lunar Mansions).

Constellation 40. The Ship [Argo Navis]

FIGURE 81

Aratus (lines 342–352) described the constellation as being the ship Argo belonging to the legendary Jason, who sailed in it with the Argonauts from Iolchis in Thessaly to Colchis at the farthest end of the Black Sea to seek for the Golden Fleece; when the voyage was over the ship was placed in the heavens by Athena. The constellation of Ἄργω sails with its stern foremost or backwards. Aratus says:

> For not hers is the proper course of a ship in motion, but she is borne backwards, reversed even as real ships, when already the sailors turn the stern to the land as they enter the haven, and every one backpaddles the ship, but she rushing sternward lays hold of the shore ([trns.] Mair, 235).

The high-curving stern, which lies very close to the tail of Canis Major, was called by Ptolemy χηνίσκος, the usual term for such sterns of Greek ships, since they frequently turned up like a goose's neck (χήν). The ship had one mast and two rudders or long steering oars. The prow of early Greek ships of war was formed by a low beak or ram, ἔμβολος, which projected from the keel and which was driven into hostile ships. It was not until later that the prow rose as high as the stern. Thus the older style ship may have given rise to the notion of its being a ship cut in half, as Ptolemy seems to indicate in his placement of the stars in his catalog when he speaks of the cutting off (ἀποτομή) of the deck (see Chapter 4 of this study for a comparison of the ship on the Smithsonian globe with that on other globes).

In the Islamic world this constellation was called *ṣūrat al-safīnah* (the constellation of the ship), as it is written between the flag on the stern and the mast in Figure 81. There is some evidence (Kunitzsch [1961], no. 259) that the early Arabs viewed a ship in another area. However, the only accounts of it place the ship from the area under the stars forming *al-dalw* (the bucket [*δγβα Pegasi*]) to *sa^cd al-su^cūd* [*βξ Aquarii* and c[1] *Capricorni*] with the bow on "the anterior frog" [*α Piscis Austrini*] and its stern on "the following frog" [*β Ceti*]; this appears an impossible arrangement and is nowhere near the Ptolemaic Argo. Al-Ṣūfī (*Ṣuwar*, 303) in his discussion of Argo reports this tradition but dismisses it by saying "but those who say this knew neither *al-safīnah* (the ship) nor *al-su^cūd* nor the 2 frogs. But Allāh is wisest and knows best." The constellation of Argo was considered to have 45 formed stars and no unformed ones. It was mentioned as early
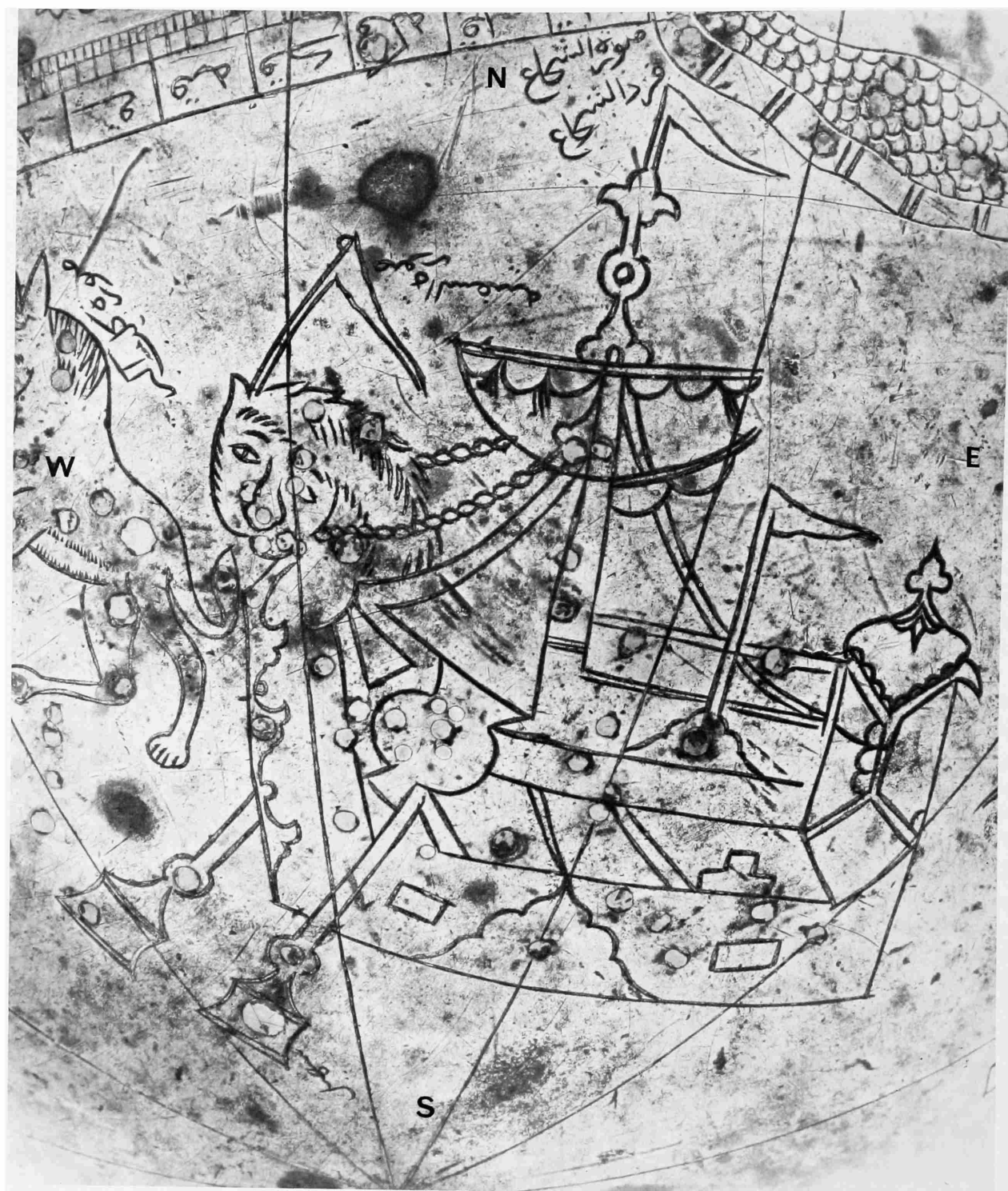
FIGURE 81.—The Ship [Argo Navis]. (Photo: Smithsonian no. 72-3102)

as Aratus as well as by al-Ṣūfī that the Milky Way passed through part of the stern of the ship. The area covered by the classical constellation of Argo Navis is today most frequently divided into four constellations: Carina (the keel), Puppis (the stern), Vela (the sail), and Pyxis (the mariner's compass).

The large star in the lower rudder is the second brightest star in the heavens [no. 44; α *Carinae*]. Ptolemy gave it the name κάνωβος, as had his predecessors Hipparchus and Eratosthenes. The word κάνωβος, which the modern name Canopus transliterates, was given to the star, according to legend, from the name of the chief pilot of the fleet of Menelaus, who while returning from the Trojan War stopped at Egypt. The pilot died a few miles from Alexandria, where a monument was built in his honor, a city named for him, and this star named after him. Eratosthenes also called the star περίγειος (along the earth). The Arabic word for Canopus, as can be seen in figure 81, is *suhayl*, which comes from a root having to do with a flat ground or a plain. It should be remembered that the star is very noticeable, being the second brightest in the heavens, and can be seen close to the horizon in the lower latitudes (it is not visible north of the thirty-seventh parallel), thus perhaps giving rise to a term serving as a common source for all the names associated with the earth that have been given to it (see Schoy; Kunitzsch [1959], 208–210 for Babylonian origins of the word *Suhayl*).

Canopus is the only star labeled in Figure 81. Al-Ṣūfī (*Ṣuwar*, 301) says that the traditions differ with regard to it, for some say it is called only *suhayl* (i.e., without an adjective, *ᶜalā al-iṭlāq*) while the stars of second magnitude near it—the star in the center of the oar-top, the star at the base of the easternmost flag, and the large star to the east of the oar-top above the hull line [nos. 17, 31, 35; ζ *Puppis*, λγ *Velorum*]—are called *suhayl bulqīn* (?), *suhayl ḥaḍār* (an earthy *suhayl*), *suhayl al-wazn* (the *suhayl* of the weight), and *suhayl al-muḥlif wa al-muḥnith* (?). The meanings of all these names are obscure (Kunitzsch [1961], nos. 272,273). Another indigenous Arab word for Canopus used by other authors (Kunitzsch [1961], no. 84) is *al-faḥl* (the male camel). Ibn Qutaybah cites a verse using this term and adds afterwards that the poet "compared it to a male camel who is no longer able to mate and has isolated himself [from the rest of the camels]" (Kunitzsch [1961], no. 84).

Constellation 41. The Serpent [Hydra]

FIGURE 82

Aratus (lines 443–448) calls this constellation ὕδρα, a hydra or water-serpent, whose head is beneath the middle of the crab, its coil below the lion (Leo), and its tail above the centaur. About midway in its form is set the constellation of the jar (Crater) and close to the end of the tail is the form of a raven (Corvus) which appears to peck at the Hydra. The Islamicate representation follows the Ptolemaic; a detailed view of the lower half of Hydra with the constellations of Crater and Corvus can be seen in Figure 83. This asterism of a serpent with a bowl and raven may possibly be of Babylonian origin and it has been suggested that the serpent and the raven are symbols of darkness and evil, with the huge jar symbolizing the "vault of heaven wherein at times storm, wind, clouds and rain are chaotically mixed" (Brown, I:107). Greek mythographers (e.g., Hyginus, II, 40) identified the Hydra as being the Lernaean hydra of the Hercules legend. The raven was said to be a servant of Apollo who was sent to fetch a cup of pure water for a sacrifice; the raven encountered a fig-tree en route and waited for the figs to ripen; when he returned to Apollo he brought a snake saying the snake had prevented him from getting the water from the spring. Apollo punished the bird so that when the figs are ripe, it cannot drink water. The constellations were placed, according to Hyginus, so that the crow seems to peck at the serpent to be allowed to go over to the bowl of water.

In Arabic Hydra is called *al-shujāᶜ* "the large snake or serpent," as in the title written on the Smithsonian globe beneath the coil of the snake.
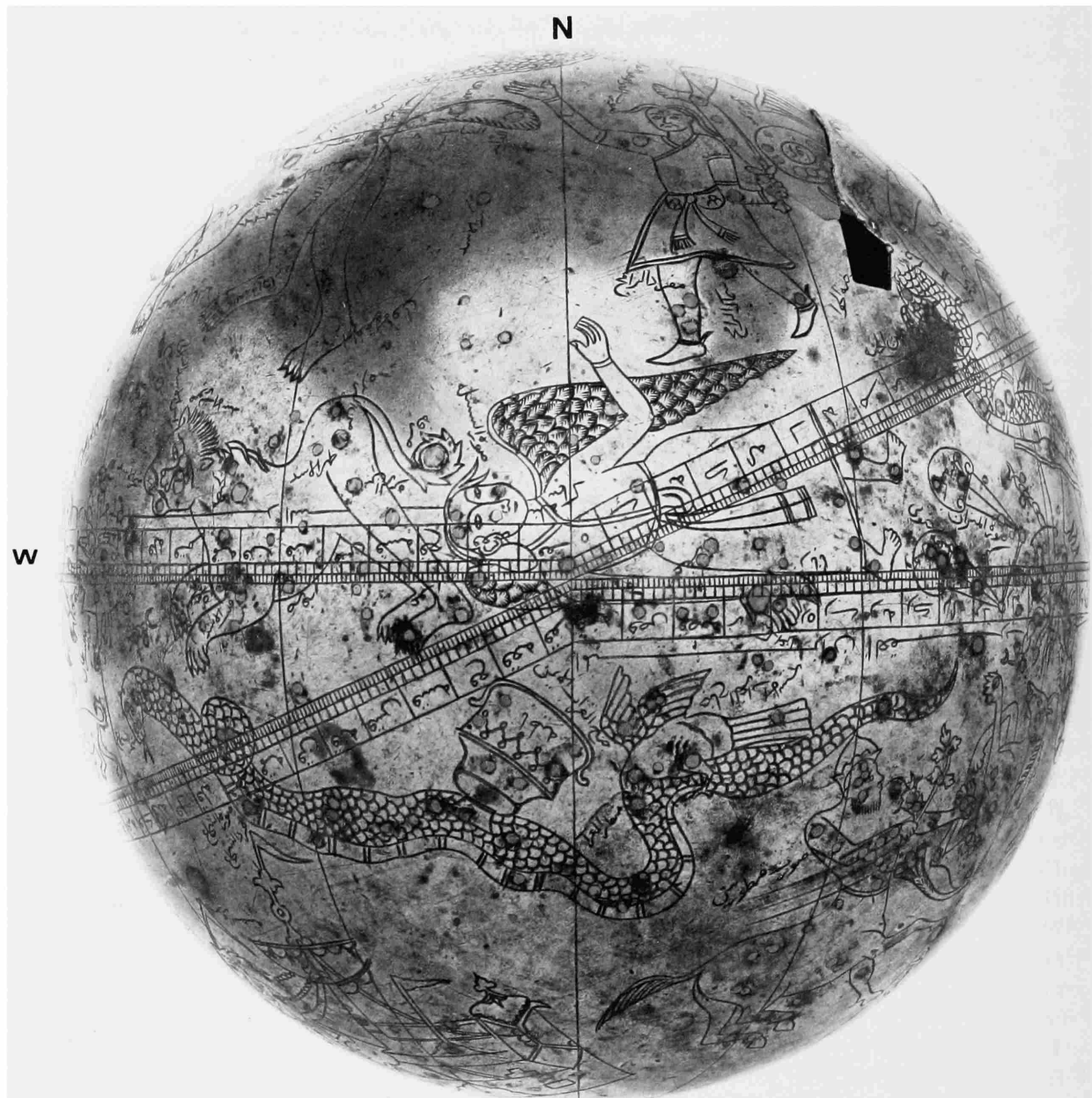
FIGURE 82.—The Serpent [Hydra]. This view shows the area around the autumnal equinox. (Photo: Smithsonian no. 72-3083)

The constellation is composed of 25 formed stars and 2 unformed ones. One of the latter is located to the north of the equator near the top of the coil at 150° of the equator. The other unformed star is in the graduations of the equator at about 130° and is beneath the head of Hydra. In Figure 83, which shows the lower half of Hydra, the star in the tail of the raven (Corvus) is misplaced, for it should be in the tail of Hydra as no. 24 of the constellation. There are two stars named in Hy-

dra on the Smithsonian globe. The first one, the anterior of the two on the nose of the serpent, reflects the Ptolemaic outline. This star, no. 1 of the constellation, is labeled *mankhar al-shujā*ᶜ (the nose of the serpent [σ *Hydrae*]).

The other labeled star is the larger of the two contiguous stars beneath the coil, no. 12 [α *Hydrae*]. This star is labeled *fard al-shujā*ᶜ (the isolated one of the Serpent) and it is from this name that the modern name of α *Hydrae*, Alphard, arises. Al-Ṣufī (*Ṣuwar*, 309) also calls this star, which he says is written on astrolabes, ᶜ*unq al-shujā*ᶜ (the neck of the serpent), a name it bears on certain other globes (e.g., Nos. 4, 26, and 31). *Fard* (the solitary) is a traditional Arab name for the star, according to al-Ṣūfī (*Ṣuwar*, 312), "because of its seclusion from things similar to it and its turning toward the south."

In the Bedouin tradition the stars of Hydra between *fard al-shujā*ᶜ and the stars of Corvus the Raven, that is nos. 13 (the first below *fard*) through 23 (in the triangle to the south of Corvus), are called *al-sharāsīf* (the cartilages of the ribs). Kunitzsch ([1961], no. 284) interprets the word to mean "the fettered camels" and identifies the stars as $\kappa\upsilon^{1,2}\mu\varphi\nu$ *Hydrae*, β *Crateris* and $\chi^1\xi o\beta$ *Hydrae*. Al-Ṣūfī (*Ṣuwar*, 313–314), also gives several other traditions for the placement of *al-sharāsīf*, but concludes that all others are incorrect.

Al-Ṣūfī mentions several stars overlooked by Ptolemy, including one north of *fard*. He mentions a row of stars between Hydra and the stars of the Lion which inclines far under the foot of the Lion toward the northeast until it reaches the fifth star on the southern shoulder of Virgo (the star that is the first lunar mansion).

Al-Ṣūfī (*Ṣuwar*, 314) also states:

> The second unformed star of Hydra, between Hydra and Leo, along with the bright stars of Leo which fall in a line, along with the remainder of the constellation of Hydra are called *al-khayl* (the horses). And the small stars which are around them are called *aflā*ᵓ *al-khayl* (the colts of the horses); and near them is the constellation of the Jar, between *al-fard* and the constellation of the Raven, and it is called *al-ma*ᶜ*laf* (the manger).

Constellation 42. The Jar [Crater]

FIGURE 83

Aratus (line 448) mentions that on the back of Hydra there is a κρατήρ, a large bowl or vessel in which wine was mixed with water and from which the cups were filled. In some Greek writings, such as the histories of Polybius (XXXIV, 11.12), the word is used for a mouth of a volcano. Thus the latinized form of the word, Crater, has generally the latter connotation in English and not the early idea of a large earthenware bowl or vessel, which is intended in the name of the constellation. The constellation of Crater is inseparably bound with the raven (Corvus) and Hydra, both in its ultimate Babylonian origin and in most later Greek legends associated with it (see the discussion of Hydra and Figure 82). One legend (Hyginus, II,40) connects Crater with the cup of Ikarios to whom Dionysus gave the vine and who was translated into the skies as the constellation Boötes.

In the Islamic world κρατήρ was translated as *bāṭiyah* (a jar), which can be observed to be written across the decorative vessel in Figure 83. None of the seven formed stars comprising the constellation are given individual names. The traditional Bedouin term for this circular group of stars was *al-ma*ᶜ*laf* (the manger) and was associated with the nearby stars of Hydra, which were called "horses" and "colts" (al-Ṣūfī (*Ṣuwar*, 313, 318).

Constellation 43. The Raven [Corvus]

FIGURE 83

A figure of a raven, κόραξ in Greek, was described by Aratus (line 449) and later writers as seeming to peck at the Hydra. According to the mythographers the Raven, who was a servant of Apollo, was placed in the skies along with the Jar and the Snake as punishment for having lied to Apollo when he blamed the snake for his delay in fetching water instead of admitting he had tarried to wait for a fig tree to ripen.
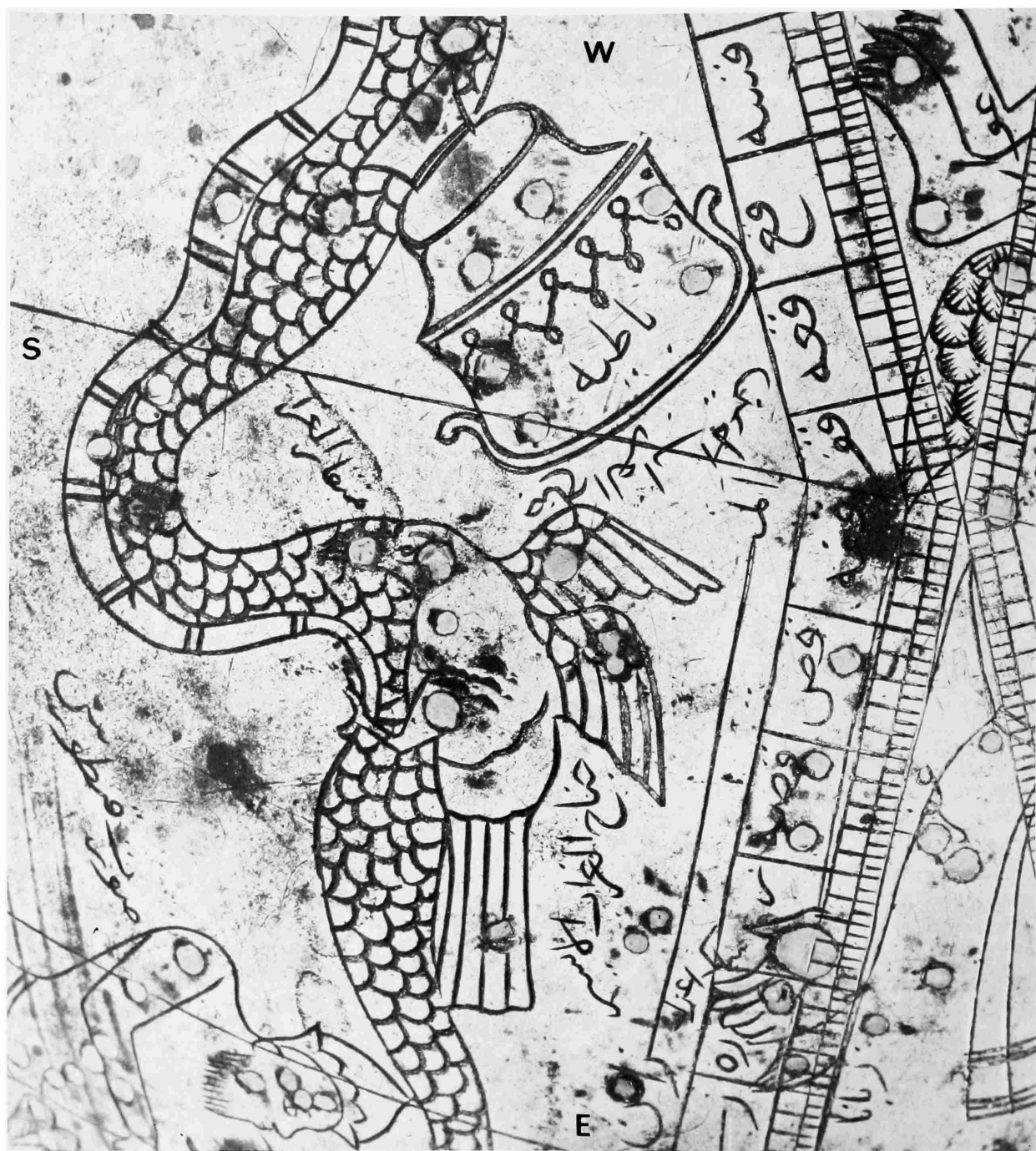
FIGURE 83.—The Jar [Crater] and the Raven [Corvus]. (Photo: Smithsonian no. 72-3104)

In the Arabic world the Ptolemaic constellation was translated as *al-ghurāb* (the raven). A formal title is not given to the constellation in Figure 83.

The names given the individual stars in Figure 83 all reflect the Greek-Ptolemaic conception of the asterism as translated into Arabic. The star in the bill of the raven is labeled *minqār al-ghurāb*

(the bill of the raven) and is the first star of the constellation [α *Corvi*]. The fourth star, the one on the wing closest to the jar (Crater) is called *jināḥ al-ghurāb al-ayman* (the right wing of the raven [γ *Corvi*]). The larger and anterior star of the two on the other wing, no. 5, is termed *jināḥ al-ghurāb al-aysar* (the left wing). This star, δ *Corvi*, is today called Algorab from the Arabic word for raven.

In the Bedouin tradition according to al-Ṣūfī the stars comprising this constellation were called *al-khibāʾ* (the tent) and *al-ajmāl* (the camels; al-Ṣūfī [*Ṣuwar*, 321] reads *aḥmāl*, which seems unlikely). They were also called *ʿarsh al-simāk al-aʿzal* (the throne or pavillion of the unarmed *simāk*), which is a reference to the large star Spica in Virgo (Kunitzsch [1961], no. 40). This star in Virgo was viewed as one of the back legs of a large lion by the early Arabs. Spica can be seen in the hand of Virgo to the north of the tail of Corvus in Figure 83. The stars were also called *ʿajz al-asad* (the buttocks of the lion). Al-Ṣūfī adds that it is asserted that sometimes the moon falls short and so resides with *ʿajz al-asad*—that is, that sometimes it is a lunar mansion.

The constellation of Corvus consists of seven formed stars and no unformed. In Figure 83, eight stars can be seen within the form of the Raven; however, the one on the tail is misplaced, and should be directly to the south in the body of Hydra as the twenty-fourth star of Hydra.

Constellation 44. *Qīnṭūrus* [Centaurus]

FIGURE 84

In the Greek conception of the sky this constellation is the second centaur, the other being Sagittarius who was half human and half horse. This centaur was called by Aratus and later Hipparchus and Ptolemy, simply κένταυρος (the centaur). Aratus (lines 436–443) says the constellation of Centaurus is placed beneath Scorpio and the Claws (Libra), but Hipparchus (*Comm. arat.*, I,8.21) corrects him by saying that the constellation is nearly all under Virgo, which is north of Hydra and Corvus seen above his head. Aratus also mentions that in his right hand he grasps a wild-beast, θηρίον. This animal was variously interpreted as several different wild animals, and even at times confused with the constellation of the Hare or Cetus the sea-monster, but most frequently he was regarded as a wolf; it can be interpreted as representing another type of darkness. Writers subsequent to Aratus (e.g., Erat. *Catast.*, 40; Hyginus, II,38) stated that the Centaur carried in his other hand a θύρσυς, a thyrsus or wand carried by devotees of Dionysus (Bacchus), which was a phallic symbol consisting of a stick wreathed in ivy and vine leaves with a pine cone on top. The Greek legend most frequently associated with Centaurus was that of the wise Cheiron who reared and taught Asclepius and Achilles and surpassed all other centaurs and men in justice. The scholiasts of Aratus, Germanicus, and the author of the pseudo-Eratosthenes *Catasterismi* even called the constellation χείρων, Cheiron. Others associated it with Pholus, the most skilled of all centaurs in augury and hence say that it is approaching the altar (the constellation Ara seen in front of him) with a sacrificial victim (the wild beast).

In Figure 84 the centaur is bearded and holds some vine leaves in one hand and an unidentified type of animal in the other (the forty-fifth constellation Lupus). In the Arabic world the constellation of the centaur was called *qīnṭūrus*, a transliteration of the Greek word for centaur (see Kunitzsch [1974], 200–202]. The figure is titled over his back *Ṣūrat al-Qīnṭūrus* (the constellation of the Qīnṭūrus). Al-Ṣūfī explains that it is an animal whose foresection is that of a man and whose back quarter is that of a horse. He called (*Ṣuwar*, 334) the object he carried the *qaḍīb al-karm* (the rod of the vine). Al-Ṣūfī adds (*Ṣuwar*, 323), "Ptolemy said there are 37 stars, but there are 36 stars, the thirtieth being incorrect." Further on al-Ṣūfī gives the coordinates of the thirtieth star as given in the *Almagest*, but adding "but there is no star there which vision can perceive." Nonetheless, al-Ṣūfī left it in his catalog that followed at the end of his discussion, and five centuries later Ulugh Bēg also kept it in his catalog although noting, as had al-Ṣūfī, that

FIGURE 84.—*Qīnṭūrus* [Centaurus]. (Photo: Smithsonian no. 72-3105)

it could not be observed. The star appears on all globes studied and is the small, lower star of the three forming a triangle on the belly of the centaur. In Figure 84, 37 stars make up Centaurus; the lower star in the hand holding the constellation Lupus is to be counted with the wild animal and not with the centaur. There are no unformed stars of Centaurus, the one under the belly being counted as formed. The only star labeled in Figure 84 is the thirty-fifth star of the constellation labeled *rijl al-qīnṭūrī* (probably an engraving error for *al-qīnṭūrus*), meaning "the foot of the centaur." This star is the third brightest in the firmament and the nearest to us. Its name today is Rigil Kent, obviously derived from the Arabic title.

In the Bedouin tradition no. 35 [*α Centauri*] on the extended front leg and no. 36 [*β Cen*] on the other front leg were together called *ḥaḍār wa al-wazn*, whose meaning is somewhat obscure, but could roughly be translated as "a poised object and the weight" and has been compared to the sun and the earth. Al-Ṣūfī (*Ṣuwar*, 333) says he does not know which is *ḥaḍār* and which *al-wazn*; however, no. 36 he thinks resembles *ḥaḍār*, a poised object, because it rises before no. 35, but he notes that they always write *ḥaḍār* first and *al-wazn* second (cf. Kunitzsch [1961], no. 118). The name *ḥaḍār wa al-wazn* is written between these two stars on globes Nos. 4 and 5. The "modern" name of *β Centauri*, no. 36, is Hadar. Al-Ṣūfī also remarks that the two stars were called *maḥlifān wa maḥnithān* as well, "the two swearings of oaths and the two violations of oaths" because when the first one rises a person would swear it is *suhayl* (Canopus), but when he sees the second one rise he realizes it was not Suhayl and that he perjured himself in swearing that it was.

Constellation 45. The Wild Beast [Lupus]

FIGURE 85

The animal held by the centaur constitutes a separate constellation. In Figure 85, which presents an overall view of the area around the winter solstice on the Smithsonian globe, this constellation can be seen in the lower left-hand corner (for a detailed view see Figure 84). On the Smithsonian globe the constellation is titled *ṣūrat sab*ᶜ (constellation of the wild beast), being a direct translation of the Greek *θηρίον*. Al-Ṣūfī (*Ṣuwar*, 329) says of this constellation "there are 18 stars, but Ptolemy says there are 19." The star numbered 11 in the constellation, he continues, is according to the *Almagest* the southern of the 3 in the end of the tail, "but there is no star there which the vision perceives." Yet here again al-Ṣūfī included the eleventh star in his catalog, noting that he could not observe it. Similarly, Ulugh Bēg stated in the introduction to his catalog that he was going to eliminate the eleventh star of Lupus, but in fact he included it in the catalog just as his predecessor al-Ṣūfī had done. The star appears on all studied globes.[39]

On the Smithsonian globe there is one extra star in the constellation of Lupus: the one on the inside back thigh (marked by an arrow in Figure 84), that is the one above the north of the four stars forming a quadrilateral on the other thigh. This seems to be an error on the part of the maker, for no star appears there in the catalogs, although al-Ṣūfī does mention an extra one under the middle star at the end of the tail (but not south where no. 11 is). No stars in Lupus are labeled on the Smithsonian globe.

In the Bedouin tradition the constellations of the Centaur and the Wild Beast were viewed together as one, and indeed al-Ṣūfī treats Centaurus and Lupus together in his discussions. Al-Ṣūfī (*Ṣuwar*, 333) states that the Arabs traditionally called the stars of Centaurus and Lupus collectively *al-shamārīkh* (the vine branches loaded with fruit, or a cluster of grapes or dates). He adds that they resemble *al-shamārīkh* "because of their multitude and the thickness of all of them." This label *al-shamārīkh* is written across the two constellations on globes Nos. 4 and 5.

Constellation 46. The Censer [Ara]

FIGURE 86

This constellation, which hangs in the sky immediately beneath the tail of Scorpio between
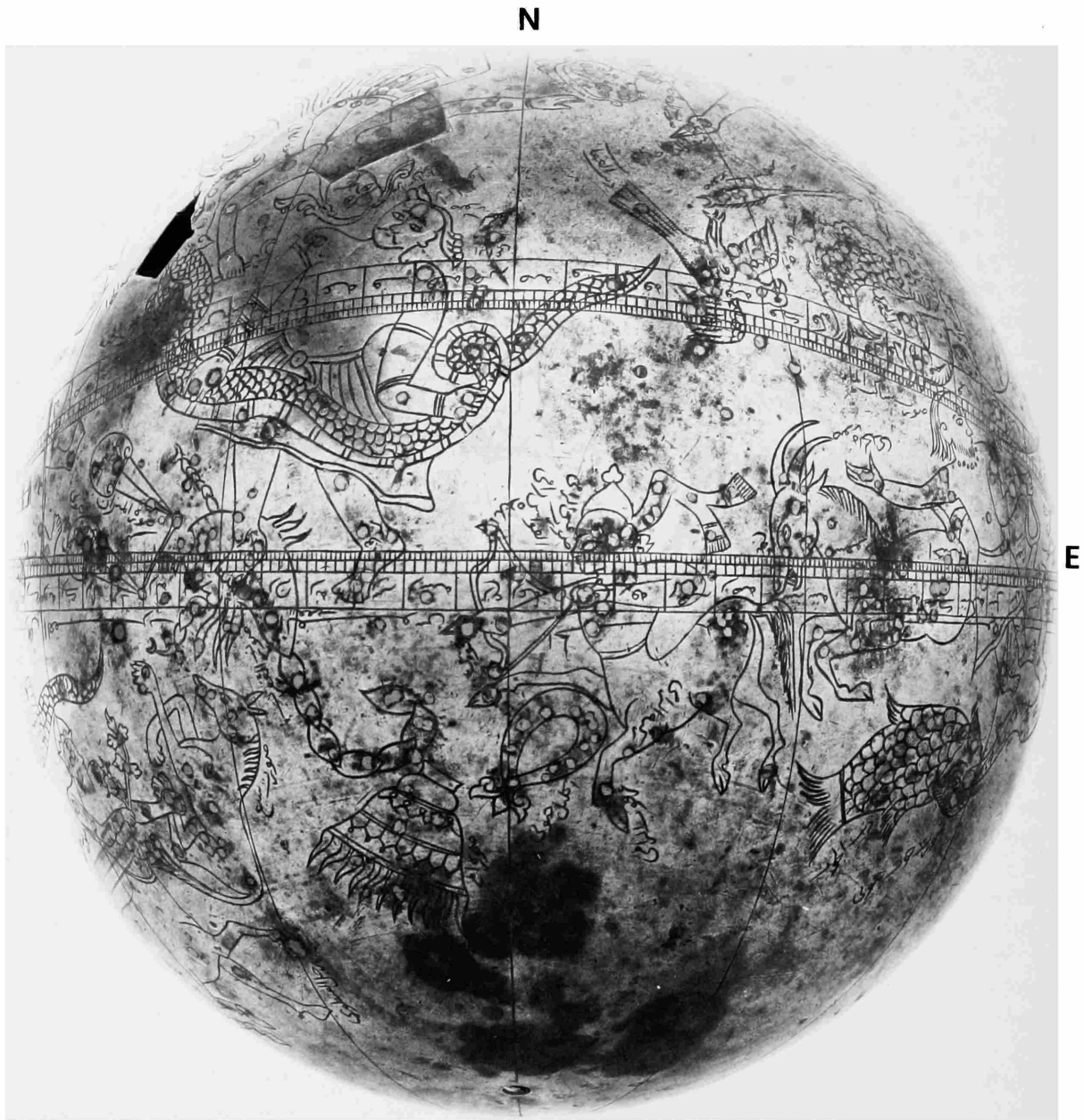
FIGURE 85.—The Wild Beast [Lupus]. This view also shows the area around the winter solstice. See also Figure 84. (Photo: Smithsonian no. 72-3081)

Lupus and Sagittarius, is the only one about which there is no Bedouin tradition: that is, the seven stars comprising the constellation do not seem to have been recognized in the Arab world before the introduction of Greek astronomy. In the Greek world the constellation, although a very small one, seems to have been an important one, for Aratus (lines 402–435) devoted an unusual amount of space to it in his poem, where he discusses the implications for storms and winds

at sea which the sighting of these stars can have for the sailor under various conditions. Aratus, pseudo-Eratosthenes, Cicero, Manilius, and Hyginus clearly viewed the form of the constellation as a sacrificial altar, calling it a *θυτήριον* in Greek or *Ara* in Latin. Hyginus (II,39) gives the legend that the gods first made offerings and formed an alliance to oppose the Titans on this altar which had been made by the Cyclopes. Some (Erat. *Catast.*, 39) add that the fire was covered so that the Titans could not see the power of the thunderbolt. Hyginus (and Erat. *Catast.*, 39) has only four stars in the constellation.

On the other hand, Eudoxus, Hipparchus (*Comm. arat.*, I,8.14 and I,11.9), Geminus, and Ptolemy thought of the constellation as a censer or vessel for burning incense, calling it *θυμιατήριον* in Greek and *Thuribulum* in Latin. It is this latter tradition which dominated in the Islamic world where the constellation is called *al-mijmarah* (the incense burner); and on all Arabic globes studied, but one, it is depicted as a censer upside down with the flames going toward the southwest. The one exception is the earliest extant globe, No. 1, where it is drawn to look like a covered furnace with a bellows, perhaps a kiln.

No stars bear individual names in Figure 86, nor do they in the texts of al-Ṣūfī or the catalog of Ulugh Bēg. Al-Ṣūfī states that the Arabs, meaning the Bedouins, say nothing about these stars. Yet in his enumeration of the stars al-Ṣūfī (*Ṣuwar*, 339) says that behind the second star of the constellation (the large star toward the east side of the base of the censer) there is a star not mentioned by Ptolemy of the fourth magnitude, which is actually doubled because right near it is a star of the sixth magnitude; moreover, he says that between this star and the second star of the constellation is another star of fifth magnitude not mentioned by Ptolemy. Such comments, which by his own statement could not have been drawn from the *anwāʾ* tradition, in addition to his constant correction of Ptolemy's magnitudes and coordinates, strongly suggest that al-Ṣūfī actually tried to observe many of the stars himself.

Constellation 47. The Southern Crown [Corona Australis]

FIGURE 86

The decorative device to the east of the censer [Ara] in Figure 86 lies between the front legs of Sagittarius (see Figure 71 for the entire constellation). It is labeled *iklīl janūbī* (southern crown), an Arabic translation of the Greek *στέφανος νότιος*, used by Ptolemy and Geminus before him. Neither Hipparchus nor Aratus used the term *στέφανος*, but the constellation may have been referred to by Aratus (line 401) by the phrase "the stars turned in a circled ring" (*δινωτοὶ κύκλῳ*).

Al-Ṣūfī (*Ṣuwar*, 344) says the Arabs differed on the constellation: some called it *udḥī al-naʿām* (the nesting place of the ostriches), with obvious reference to the ostriches seen in Sagittarius; others called it *al-qubbah* (the tent); and still others saw it as part of the Scorpion's tail.

No stars in this constellation are labeled on the Smithsonian globe. According to the star catalogs the southern crown consisted of 13 formed stars. The Smithsonian globe has only 12 stars in this constellation, however. The star that is inexplicably missing is no. 10 of the constellation [*ν Coronae Australis*] and would have been a companion star to the one that lies immediately to the northwest of the double star pictured in the constellation on the Smithsonian globe (see Figure 71). On the Islamicate globes studied this constellation is drawn either as a shapeless form (e.g., Nos. 1 and 3) or as a decorative device (e.g., Nos. 4 and 5, and the Mughal globes, Nos. 26 and the Smithsonian globe).

Constellation 48. The Southern Fish [Piscis Austrinus]

FIGURE 87

Aratus (lines 385–387) says that below Capricorn "before the blasts of the South wind swims a Fish, facing Cetus, alone and apart from the

FIGURE 86.—The Censer [Ara] and part of the Southern Crown [Corona Australis]. See also Figure 71. (Photo: Smithsonian no. 72-3103)

FIGURE 87.—The Southern Fish [Piscis Austrinus]. (Photo: Smithsonian no. 72-3111).

former Fishes; and him men call the Southern Fish (ἰχθὺς νότιος)" ([trns.] Mair, 237). Mythographers (e.g., Erat. *Catast.*, 38) recounted a legend in which Isis, when she was in labor, was saved by a fish and as a reward for this kindness she placed the fish and its young (the two fishes of Pisces) in the heavens. Hyginus (II,41) adds that for this reason the Syrians do not eat fish, and worship the gilded images of fish as household gods.

In Figure 87 the fish is labeled *ṣūrat ḥūt janūbī* (the constellation of the southern fish), a translation of the classical Greek title, though with rather poor grammar. The fish itself contains 11 formed stars, not counting the large one in the mouth at the end of the water, and such is the numbering given by al-Ṣūfī and Ulugh Bēg in their catalogs. Ptolemy, however, counted the one in the mouth in with those of the Southern Fish, even though he had already numbered it with those of Aquarius. Thus al-Ṣūfī lists 11, while Ptolemy had 12. Ptolemy also recorded six unformed stars. Al-Ṣūfī (*Ṣuwar*, 347) stated that he could not observe them, but apparently not wishing to overthrow completely the authority of Ptolemy, he nonetheless included them in his catalog of stars at the end of his discussion of the Southern Fish. He clearly labeled this section of the catalog with the statement that these six stars were taken from the *Almagest*. Ulugh Bēg on the other hand went ahead and eliminated them from his catalog. These six stars are not shown on the Smithsonian globe or on any globes made after the fifteenth century.

One star is labeled in Figure 87, the tarnished star near the end of the tail, no. 11 of al-Ṣūfī's listing. It is titled *dhanab al-ḥūt*, (the tail of the fish [κ *Piscis Austrini* or γ *Gruis*]), and seems to be labeled only on the later globes (those by the Lahore workshop and the later No. 31).

Extant Islamicate Celestial Globes

6. Descriptive Catalog

It is He who has appointed for you the stars,
that you might be guided by them
in the darkness of the land and sea.

Qur^ʾān, VI,97

Introduction

Some preliminary remarks regarding the format of this catalog of extant globes and comments on the terminology and styles of the signatures and dates are necessary. The globes are divided into three major classifications: Class A globes (Nos. 1–58) are those with the full complement of stars (1018–1025) and the outlines of the 48 classical constellations; Class B globes (Nos. 59–90) are those with only a small number of stars, usually those occurring on astrolabes, and having no constellation outlines; and Class C globes (Nos. 91–124) have no stars and no constellation forms. At the end of these three groupings are two globes that could not be classified for lack of sufficient information. There are a total of 126 globes in the catalog. Within each of these three classes, the globes are organized so that those that are signed or dated appear first, in chronological order, followed by those that are unsigned and undated. Three globes having the full set of constellation figures but no stars do not fit well into the three basic classifications, although they have been placed in Class A. Similarly, four globes having only the twelve zodiacal figures along with some stars have been placed in Class B. For further discussion of these globes see Chapter 1 and the Tables in Chapter 7.

The basic technical aspects and differences among the globes are compared in the Tables of Basic Characteristics of the Globes, which follow the catalog. The six globes listed in the Addendum to the catalog have not been included in the following comparative discussion of the globes nor in the Tables of Basic Characteristics. The Tables (in Chapter 7) include a breakdown of globes by methods of construction, when known, including the metal globes which are obviously in hemispheres, and those in which a seam is not visible but plugs are evident. Whenever a globe does not have a visible seam and also lacks evident plugs, and further examination was not possible, it has been placed in the unknown category. The Tables also include an attempted classification of globes based on the technical accuracy and precision evident in the execution of the circles and graduations. There are a number of globes, which, although maintaining the basic form and design of one of the three basic classes, have been executed by an artisan who was not a professional instrument maker, with the result that the graduations are uneven, the circles not precisely delineated, and other technical features are inaccurate, so that the globe cannot function as a true astronomical instrument. Occasionally these technically inaccurate and non-functional globes are outstanding examples of fine metal-working or calligraphy.

Only two globes with dates prior to the sixteenth century are inscribed in *naskhī* script; the other early globes are engraved in Kūfic script. The globe made by Qaysar (No. 3) in 622 H/AD 1225–1226 for the nephew of Saladin has both labels and the signature in *naskhī* script. This globe is unique in that the constellations bear engraved Latin titles as well as Arabic ones, and the ecliptic and equator are numbered with the European form of Arabic numerals as well as the *abjad* letters of the alphabet commonly used in the Near East; such inscriptions were possibly engraved well after the globe was actually constructed. The other globe dating prior to the sixteenth century to be inscribed in *naskhī* script is a globe bearing the date of 718 H/AD 1318–1319 made by ʿAbd al-Raḥmān ibn Burhān al-

Mawṣilī (No. 60); the authenticity of this date is, however, questionable.

Signatures were usually placed around or near the south poles for the simple reason that space was to be found there since the southernmost constellations had not yet been mapped and were not represented on Islamicate globes, even those made as late as the nineteenth century. A transcription of all the imprint inscriptions on the globes will be found in Chapter 8.

On the globes possessing makers' names, the word used most frequently as the equivalent of the Latin *opus* is *ṣanʿah*. Interpreting the word as the noun *ṣanʿa(t)* (product), in construct with the maker's name, rather than the verb *ṣanaʿahu* (he made it) seems preferable, since the Arabic word for globe, *kurah*, is always feminine and would require a feminine object, thus *ṣanaʿahā* rather than *ṣanaʿahu*. Furthermore, on several globes (e.g., Nos. 11–14) there are clearly dots over the final letter, indicating that the maker intended the final letter to be a *tāʾ marbūtah* and hence the word to be a noun rather than a verb. The word *ṣanʿah* is used on all but two of the globes dated prior to the sixteenth century as well as on globes by the seventeenth-century metal-workers Muḥammad Zamān (Nos. 16 and 64) and Luṭf Allāh ibn ʿAbd al-Qādir al-Muḥibb (No. 67), and the globes made in Mughal India by Qāʾim Muḥammad (Nos. 11–14), his brother Muḥammad Muqīm (No. 15), and his nephew Ḥāmid (No. 68) of the Lahore workshop. The very earliest Islamicate globe known today, made in Moorish Spain in 473 H/AD 1080 employs the verb from this same root reading *ṣanaʿa hādhihi al-kurah* (Ibraham ibn Saʿīd . . . made this globe), as does globe No. 10 by ʿAlī Kashmīrī ibn Lūqmān which reads *ṣanaʿhā* (he made it [the globe]).

The most prolific member of the Lahore workshop, Ḍiyāʾ al-Dīn Muḥammad the son of Qāʾim, employed on his earliest globes (Nos. 18 and 19) the word *ṣanʿat,* where he wrote the *tāʾ marbūṭah* as a simple final *tāʾ*. On all of his other globes, however, Ḍiyāʾ al-Dīn used the word *ʿamal* in the sense of "work" or *opus* (Nos. 20–24, 26–28, 30, 66, 69, 71).

The use of the word *ʿamal* is usual with Ḍiyāʾ al-Dīn of the Lahore workshop as well as later makers such as Muḥammad Ṣāliḥ Tatawī (Nos. 25 and 29) of the seventeenth century, Riḍwān who constructed his globe in 1112 H/AD 1701 (No. 31, where the term occurs in the expression *kumila ʿamal hādhihi al-kurah* [the construction of this globe was carried out]), and Muḥammad Karīm (No. 74) of the first half of the nineteenth century. The word *ʿamal* occurs only twice on globes before the seventeenth century: on the sixteenth-century globe by Jamāl al-Dīn Muḥammad ibn Muḥammad al-Hāshimī al-Makkī (No. 9) which is clearly a poorly constructed and non-functional globe, and that dated 718 [H]/AD 1318–1319 by ʿAbd al-Raḥmān ibn Burhān al-Mawṣilī (No. 60) which is non-functional and also of questionable authenticity.

Very few other words are employed to describe various aspects of the construction or design. On globe No. 72 the noun *rasmah* (inscription) is found in construct with the maker's name Muḥammad Ashrāf Tuqādī Zādah. I prefer the reading of it as a noun rather than as a verb *rasamahu* for the same reason that I prefer *ṣanʿah* to *ṣanaʿahu*. In the context of this particular globe, it is likely that the maker intended to indicate by *rasmah* that he inscribed the surface design of the sphere, the sphere itself having actually been fashioned by another workman. Since he also signed the stand "the work of (*ʿamal*) Muḥammad Ashrāf," he may actually have constructed the stand as well as incised the graduations on it, while on the sphere he may have drawn the surface design onto a sphere that was made by another craftsman out of wood or possibly ivory. The design and graduations of this particular globe and stand were executed with impressive precision.

The passive verb *rusimat* occurs when referring to the positioning of the stars on the globe by Muḥammad ibn Maḥmūd al-Ṭabarī (who also uses the noun *kutub* in the sense of "inscription") in 684 H/AD 1285–1286, (globe No. 6), and on the products of the fourteenth-century astrolabe and globe maker Jaʿfar ibn ʿUmar and his son Muḥammad (Nos. 7, 8, and 62) as well as one anonymous seventeenth-century globe (No. 65). The globe made in 1069 H/AD 1659 by Ḥāmid

of the Lahore workshop (No. 68) employs the verbal noun *taḥrīr*, meaning the act of composing or writing, used here apparently in the sense of engraving the words on the globe. The globe made in 1221 H/AD 1806 by Muḥammad ʿAlī al-Ḥusaynī (No. 73) uses the modern Arabic construction of a passive with agent, *tummat ʿalà yad* (it was finished by the hand of), while the Ottoman Turkish globe made in 1229 H/AD 1882 by Ḥusayn Ḥüsnü Kanqarlī (No. 75) refers to the construction (*ikhtirāʿ*) of the globe, a similar word being used on the earlier sphere (No. 30) made in 1090 H/AD 1679–1680, which states that the sphere was constructed (*ikhtirāʿī*) by Ḍiyāʾ al-Dīn Muḥammad, here used perhaps more in the sense of invention since the design of this sphere is quite unique.

The expression *bi-rasm* is used in two senses by Qayṣar (No. 3, dated 662 H/AD 1225–1226); first, in the sense of "by the design of Qayṣar ibn . . ." and then secondly to mean "by the order of" the patron. The expression *bi-rasm* is used in a similar manner to indicate the patron on the eighteenth century globe by Riḍwān (No. 31) and the somewhat questionable fourteenth-century globe by ʿAbd al-Raḥmān ibn Burhān al-Mawṣilī (No. 60), which also seems to have the curious expression *maṭwà bar naẓar* (undertaken at the instigation of) and the name of yet another patron. In a similar way the Persian expression *ḥasb al-amr* is used to express the patronage of Shāh ʿAbbās the First (No. 63), while on an early eighteenth-century globe (No. 32) the dedication to a patron seems to begin *bar ḥasb.* On two Mughal globes (Nos. 25 and 30) the Persian *bi-farmāyish* indicates the patron. The globe made in the Punjāb in AD 1842 by Lālah Balhūmal Lāhūrī employed *bi-tajwīz* to indicate patronage (No. 33).

An unsigned and undated globe gives the name of a patron who requested that it be made and figured (No. 37), *istaṣnaʿahu wa istaṣwarahu* using a specific verb to indicate the engraving of the full set of constellation figures upon the globe. On the earliest globe made by the Lahore workshop (No. 11), the proprietor's name, in this case probably also the patron, is indicated by the formula *ṣāḥibuhu nawāb*, while a similar expression, *mālikuhu nawāb* is found on a nineteenth-century globe (No. 92). A nineteenth-century owner of one globe (No. 59) indicated possession by the expression *min mumtalakāt.*

The names of the makers are frequently preceded by self-deprecating formulae such as "the one who is in need of God the Merciful" (No. 4) or the expressions so common on the globes produced by the Lahore workshop, *aqall al-ʿibād* (the least of the servants [of God]) and *aḍʿaf al-ʿibād* (the weakest of the servants). Particularly elaborate formulae were used by the Ṣafavid Persian maker Muḥammad Zamān, who refers to himself as "the dust of the threshold of Riẓā (*turāb ʿatabat al-riẓā*; No. 16), a reference to the sanctuary of an Imām in Mashhād where he worked, and the Persian expression *khak rāh ān* (the dust of the road of life; No. 17).

The basic language for all Islamicate celestial globes is Arabic, in that the technical terminology and star names are written in Arabic, with the exception of the two Sanskrit globes (Nos. 29 and 54), one of which has the constellation names written in both Arabic and Sanskrit. Some of the signature inscriptions and statements of patronage on the later globes are in Persian, or Indo-Persian, or in one instance in Ottoman Turkish, and many of the later signatures employ one or two words of Persian. Only very occasionally do Persian words occur in the technical vocabulary itself (for example, on Nos. 30 and 94), and then usually only prepositions or pronouns. The grammatical structure and orthography of the Arabic on the later globes, however, frequently reflect a maker whose main language is Persian or Indo-Persian (a form of Persian common in parts of India such as the Punjāb) or other eastern dialects of Persian such as Tājīk, which is spoken in southern Turkestan.

Occasionally the date of the globe is given in several eras besides that of the Hijrah, such as that of the Yazdijird era (Sassanian solar calendar reckoned from AD 632), the Alexandrian era (Seleucid era calculated from 312 BC), the Year of the Flood (a Coptic calendar) and the Malikshāh era (Jalālī), an eleventh-century reform of the older Persian solar calendar. The year of construction given in terms of the year of the

reign of one of the Mughal emperors, Akbar, Jahāngīr or Shāh Jahān, occurs on several Indo-Persian products. And on a nineteenth-century product of Lahore (No. 33) the date is given in terms of the Vikrama era still current in India today as well as in the Christian era (see Table 5 in Chapter 7; for details on various calendars see al-Bīrūnī [*Chron.* [trns.], 16–36, 136–380], Carra de Vaux, and Taqizadeh).

Generally all the globes made before the sixteenth century express the year in *abjad* letters, while all those made in the sixteenth century and later employ standard numerals for the dates. The exceptions to this pattern are the thirteenth-century globes by Qayṣar (No. 3) and Muḥammad ibn Maḥmūd al-Ṭabarī (No. 6), both of which use standard numerals, while the anonymous globe made in 1056 H/AD 1646–1647 uses *abjad* numerals (No. 65). The globe by ʿAbd al-Raḥmān ibn Burhān al-Mawṣilī (No. 60, dated 718 H/AD 1318–1319 writes the dates out in words, as does the nineteenth-century one by Lālah Balhūmal (No. 33).

Each globe in the catalog is described in as much detail as possible, either from personal examination of the globe or from photographs or published descriptions. Unless otherwise stated, the entry is based on personal examination. Following the description of the globe and statements as to the provenance of the globe if known, citations are presented to studies, reproductions, or references to the globe (a full list of the abbreviations will be found in the bibliography). For the better known globes only the most important or very recent citations are listed, the other citations being referred to in the places cited, so that if all the items listed are consulted all known reproductions or descriptions of the globe can be located.

A full transcription of all the signature inscriptions and other major inscriptions is to be found in Chapter 8 where the numbers correspond to the catalog numbers of the globes. The inscriptions on all the signed globes will also be described in the *Répertoire des facteurs d'astrolabes et de leurs oeuvres, Première partie: Islam*, by A. Brieux and F.R. Maddison, who generously gave me access to their files while I was preparing this catalog. Since the *Répertoire* has not yet been completed and published, however, I have not in each instance given a citation to the forthcoming *Répertoire*.

Since the precise number of stars on a globe very frequently differs from the number given in standard catalogs and even, on occasion, from the total specifically stated on a globe, usually because the maker inadvertently adds or omits some stars or sometimes purposefully adds an extra star such as the "overlooked star" in Ursa Major, in the present catalog the number of stars is always qualified by "approximately" unless the specific number has actually been counted. The approximate number given for Class A globes depends on which star catalog the maker was likely to have been using (i.e., Ptolemy with 1025 stars, al-Ṣūfī with 1024, or Ulugh Bēg with 1018).

Unless otherwise stated a globe has holes drilled at the two (celestial) equatorial poles, so that the axis of rotation could pass through the celestial poles. The term "equator" on a globe, of course, refers to the celestial equator. In regard to the rings, the phrase "non-consecutive segments of 90°" is used to describe a labeling such as that illustrated in Figures 31, 32, and 33—that is, the ring is divided into four quadrants, but the graduations are arranged so that there are only two points, diametrically opposite, that serve as zero points, the other two points separating the quadrants being marked 90°. The numbering on the ecliptic, equator, and rings is with *abjad* numerals unless otherwise specified.

In the descriptions of some globes I have referred to there being inscriptions in double-outlined writing. This term is intended as an aid in grouping together globes that have the common characteristic of labeling, most frequently of the zodiacal names, with each letter formed by parallel lines producing a wide brush-like stroke rather than the usual engraving with letters formed by single lines. Examples can be seen in Figures 7 and 20, the former showing a narrow

form of double-outlined writing.

When a metal globe appears to be seamless, it has been stated in this catalog that it has "no seam observable" rather than stating that it is a seamless cast globe, because only examination of the inside or use of radiography can determine with certainty whether such a globe was raised or cast. Whenever plugs are visible, it is also noted. In the case of the Smithsonian globe (No. 38), tests of course have confirmed that it was cast by the *cire perdue* process. No attempt has been made to distinguish the copper alloys, brass and bronze, or the quaternary alloy commonly used in cast objects, for the actual composition of the alloys varied greatly and only laboratory analysis can determine the nature of the alloys employed.

See Chapter 2 for a discussion of the methods of construction and the design and function of the three basic types of Islamicate celestial globes and Chapter 1 for a discussion of the individual known globe makers.

The Catalog

Class A—Celestial Globes with Constellations

Signed or Dated

1.

Location: Florence, Istituto e Museo di Storia della Scienza; Inventory No. 2712.
Date: The first of Ṣafar of the year 473 H [22 July AD 1080] (or the first of Ṣafar 478 H/28 May AD 1085).
Maker: Ibrāhīm ibn Saᶜīd al-Sahlī al-Wazzān with his son Muḥammad.

Metal; in hemispheres with seam along equator. Diameter 209 mm. Forty-seven constellation outlines; Crater is not drawn or labeled, though the stars are present. Has 1015 stars, each indicated by a dot inside an engraved circle. Ecliptic latitude circles; southern equatorial polar circle, around which there is the inscription giving the maker. Ecliptic and equator graduated by single degrees with every fifth labeled; ecliptic repeats every 30°, equator is labeled continuously from vernal equinox. Zodiacal names engraved along ecliptic; equatorial poles, constellations, and many stars labeled; Maghribī Kūfic. Very uniform and precise globe. Signature reads:

"Ibrāhīm ibn Saᶜīd al-Sahlī al-Wazzān in Valencia together with Muḥammad his son made (*ṣanaᶜa*) this globe with stand (*al-kurah dhāt al-kursī*) for the holder of the dual office of *wazīr*, the supreme commander-in-chief (*qāᵓid*) Abū ᶜĪsà ibn Labbūn, may God prolong him and sustain him. And the fixed stars were placed on it in proportion to their magnitude and sizes. It was completed the first of the month of Ṣafar in 473 H [or can be read as 478 H]. God bless him [the prophet] and give him secure peace."

[*Dhū al-wizāratayn* means he was holder of two offices of *wazīr*, i.e., the positions of *wazīr* of war and *wazīr* of peace (*qalam*). See Meucci, 11.]

Modern wooden pedestal stand having four supports for horizon ring; ungraduated meridian ring. The rings are recent replacements and not the originals mentioned in the inscription.

Entry based on published accounts.

Citations

Meucci. Presents a lithograph reproduction of globe and analysis of terminology; says date can be read either as 473 or 478 but prefers 473.
Rep. épig. arabe, 7: no. 2727. Reproduces inscription.
Fiorini, 38–39.
Stevenson, 1:28–29.
Destombes [1957], 319, no. 2; reads date as 473.
Destombes [1958] 305–306; reads date as 478.
Mayer [1959], 51; reads date as 478.
Catalogo degli strumenti du Museo di Storia della Scienze, Florence, 1954, No. 2712.
Righini Bonelli, 156; plate 22 is color photograph.

2.

Location: Paris, private collection of M. Destombes.
Date: 539 H [AD 1144–1145].
Maker: Yūnus ibn al-Ḥusayn al-Aṣṭurlābī.

Metal; hemispheres joined together along roughly the path of the Milky Way (which is not otherwise indicated on the globe); later resoldering has marred some of the engraving. Diameter 175 mm. The walls are quite thick (6–7 mm) and the globe is very heavy; probably cast hemispheres. Modern varnish on globe; at every 90° along the seam there is a nail of different alloy.

Full set of constellation figures; about 1025 stars indicated by inlaid silver points varying in size corresponding to magnitude and numbered within each constellation. Ecliptic latitude circles; ecliptic and equatorial polar circles. Ecliptic and equator graduated by single degrees with every fifth labeled; ecliptic repeats every 30°, equator is numbered continuously from vernal equinox. Names of zodiacal signs engraved along ecliptic; equatorial and ecliptic poles, constellations, and 72 stars and 28 lunar mansions labeled; Kūfic. Very uniform and precise globe. The signature near the south equatorial pole reads: "This globe includes all the stars mentioned in the book of the *Almagest* after modifying them in proportion with the interval between the calculations of Ptolemy and the year 540 H, i.e., 15°18′. The work of (*ṣanᶜat*) Yūnus ibn al-Ḥusayn al-Aṣṭurlābī [in the] year 539".

Meridian ring missing. Metal quadruped stand on ring base with horizon ring is more recent, possibly added in eighteenth or nineteenth century during a restoration. The horizon ring is graduated unevenly by single degrees with every fifth labeled in non-consecutive segments of 90°; however, there are no notches for the meridian ring and no undersupport for the globe. The stand is non-functional, although it may have been copied from a stand that would have been outfitted with a stationary meridian ring, which would rest on the horizon ring.

Acquired about 1930 in Bombay and then sold at a public sale on 17 April 1958 at Hôtel des Commissaires-Priseurs, rue Drouot. Exhibited April-August 1976 at the exhibition "Science and Technology in Islam" held at the Science Museum, London, as part of the Festival of the World of Islam.

Citations

Destombes [1958], 300–312, 2 photographs.

Destombes [1959], 447–452. Concludes the maker was a Persian working in Iṣfahān or Rayy.

Muris & Saarmann, 36.

Mayer [1959], 296.

Guye & Michel, 210; plate 198 gives an overview of globe.

Maddison & Turner, 77.

3.

Location: Naples, Museo Nazionale.
Date: 622 H [AD 1225–1226].
Maker: Qayṣar ibn Abī al-Qāsim ibn Musāfir al-Ashrafī al-Ḥanafī.

Metal; hemispheres with seam on a plane through equatorial poles, near but not on solstitial colure. Diameter 221 mm. Full set of constellation figures engraved and damascened with copper. About 1025 stars indicated by inlaid silver points within small circles, in five different sizes to indicate magnitude. Ecliptic latitude circles; equatorial polar circles. Zodiacal names engraved along ecliptic; constellations and many stars labeled; the names of the constellations and a considerable proportion of the star names are damascened with silver; *naskhī*. Ecliptic and equator graduated by single degrees with every sixth labeled with *abjad* numerals; the equator is numbered continuously beginning at the vernal equinox while the ecliptic is numbered in intervals of 30°. Very uniform and precise graduations and circles. Every 30° interval along the ecliptic has also been labeled with the European form of Arabic numeral and the equator labeled at 100°, 200°, 300°, and 360°; engraved at a later date (?). The constellations also bear engraved Latin titles (?engraved later). Globe also has on it a scale of the five sizes of inlaid points as a guide to the stars of the first five magnitudes. It bears two inscriptions engraved in *naskhī* script and damascened with silver, both beneath the Southern Fish. The first reads: "By the order of (*bi-rasm*) the treasury (*khizānah*, i.e., library or cabinet of curiosities) of Mawlānā al-Sulṭān al-Malik al-Kāmil, the learned, the just, the defender of the world and of the faith (*al-ᶜālim al-ᶜādil nāṣir al-dunyā wa al-dīn*), Muḥammad ibn Abī Bakr ibn Ayyūb, great be his victory." The second reads: "By the design of (*bi-rasm*) Qayṣar ibn Abī al-Qāsim ibn Musāfir al-Ashrafī al-Ḥanafī in the year 622 H, with an augmentation of 16°46′ over what is in the *Almagest*."

A quadruped metal stand with legs concave in profile which meet to form a pedestal support for the meridian ring and semicircular arc hold-

ing the horizon ring. Horizon ring graduated by single degrees with every sixth labeled in Kūfic script; ring has the four cardinal points and seasons engraved near outside edge; numbering of graduations is in non-consecutive segments of 90° beginning at the East-West points and ending at the North-South points. The meridian ring is graduated by single degrees with every sixth indicated by a longer line; the European form of Arabic numerals for 30, 40(?), and 60 have been engraved along a 30° interval of the meridian ring; added later (?). Entire meridian ring may be a replacement. Incorporated into the stand are two gnomons on the west and east sides each above a 90° arc in the side of the leg directly under it; the arc is graduated by single degrees with every fifth labeled in Kūfic *abjad* numerals. The gnomons and scales allow a direct reading of the elevation of the sun. The stand and horizon ring may be contemporary with the globe.

Formerly in the Museo Borgiano, Velletri. Exhibited at exhibition "Science and Technology in Islam" held at the Science Museum, London, as part of the Festival of the World of Islam, April–August 1976.

Entry based on published accounts and photographs in the files of A. Brieux and F.R. Maddison.

Citations

Assemani. Includes three lithographed drawings which present a rather poor facsmile of the globe, and an analysis of the terms which is not always reliable.
Fiorini, 31–33.
Stevenson, 1:29
Rep. épig. arabe, 10: no. 3924; reproduces inscription.
Mayer [1956], 80–81.
Destombes [1957], 319, no. 4.
Margotta, 109 (photograph); no discussion.
Sabra [1969], 8.
Maddison & Turner, 78.

4.

Location: London. British Museum, Department of Oriental Antiquities; Inventory No. 71.3.1.

Date: 674 H [AD 1275–1276].

Maker: Muḥammad ibn Hilāl al-Munajjim al-Mawṣilī.

Metal; hemispheres joined with seam along ecliptic. Diameter 240 mm. Full set of constellation figures with about 1025 stars indicated by inlaid silver points. Ecliptic latitude circles. Ecliptic and equator graduated by single degrees with every fifth labeled; ecliptic repeats every 30°; equator beginning at vernal equinox has three segments of 100° and one of 60°. Very uniform and precise graduation and circles. Zodiacal names engraved along ecliptic; equatorial poles, constellations and many stars labeled; Kūfic. Inscription below Southern Fish, inlaid with silver, reads: "The work of (*ṣanᶜat*) the one who is in need of God, may He be exhalted, Muḥammad ibn Hilāl al-Munajjim al-Mawṣilī in the year 674 H."

An eight-lobed base frame supports four legs, concave in profile, which meet to support two crossing hemispherical bars holding the horizon ring. The latter is graduated by single degrees with the names of the four cardinal points engraved near outer edge. Labeling on ring is in *naskhī* script, indicating it is probably not contemporary with the globe. On each side of one of the hemispherical supports of the horizon ring are two devices that look very similar to the two gnomons on globe No. 3. They are positioned over the curved legs in just the same manner as in No. 3, but the concave surface of the leg is not graduated. Meridian ring missing.

Formerly in the collection of Sir John Malcolm (1796–1833), who was presented with the globe by the leader of the Bohara community whose ancestors had brought it to India from Persia. It was on deposit with the Royal Asiatic Society until 25 February 1871, when it was purchased by the British Museum from General George Malcolm.

Citations

Dorn [1830]. Includes two lithographed plates representing the constellations in each hemisphere and a detailed study of the globe.
Rep. épig. arabe, 21: no. 4708; reproduces inscription.
Fiorini, 37.
Stevenson, I:29–30.
Mayer [1956], 68.

Lehner, 122–123. Reproduces lithographed plates from Dorn.
Muris & Saarmann, 36–37.
Pinder-Wilson *BM*. Presents detailed photographs of each constellation.
Destombes [1957], 315 photograph; 319 no. 3, discussion.

5.

Location: Dresden. Staatlicher mathematisch-physikalischer Salon.
Date: None given; estimates range from AD 1278 to AD 1310.
Maker: Muḥammad ibn Muʾayyad al-ʿUrḍī.

Metal; in hemispheres with seam at ecliptic. Diameter 146 mm. Full set of constellation figures with about 1025 stars indicated in silver inlaid points. Ecliptic latitude circles damascened in silver at the zodiacal divisions. Ecliptic and equator graduated by single degrees with every fifth labeled; ecliptic repeats every 30°; equator beginning at vernal equinox has three segments of 100° and one of 60°. The two lines of the equator are inlaid with gold, while all other circles are inlaid with silver. The names of the zodiacal signs are inlaid alternately in gold and silver along the ecliptic; equatorial and ecliptic poles, constellations, and 130 stars are labeled; inscription inlaid in silver and gold; Kūfic. Near equatorial pole is the inscription: "The work of (*ṣanʿat*) Muḥammad ibn Muʾayyad al-ʿUrḍī."

Possesses a horizon ring, a meridian ring, and a zenith ring and a suspensory device by which it may be hung. Is unique among the extant globes in not having the horizon ring attached to a stand. All the rings are graduated by single degrees with every fifth labeled; metal horizon ring has the two directions (east and west) near outer edge of ring and the numbering in non-consecutive segments of 90° begins at the east-west points; metal meridian ring also numbered in non-consecutive segments of 90° beginning at points of attachment to the horizon ring.

It appears that the metal zenith ring can pivot around the globe, and it appears to have a slit the length of the upper quadrant parallel to the face of the ring. It is possible that a needle-like gnomon could have been inserted through this slit, similar to that described by al-Battānī (see Chapter 2). There is a more recent wooden quadruped stand on a circular base with a central support in which globe and rings can rest; not a functional part of the globe.

Purchased in AD 1562 by the Elector August of Saxony from Nicholaus Valerius, mathematician of Coburg. Preserved in the court art collections in Schloss Moritzburg until the early eighteenth century, when scientific instruments were placed in the Mathematisch-physikalischer Salon in the Zwinger palace. Exhibited at exhibition "Science and Technology in Islam" held at the Science Museum, London, as part of the Festival of the World of Islam, April–August 1976.

Entry based on published accounts.

Citations

Drechsler. Eight lithographs reproduce the constellations; terminology analyzed; estimates date AD 1278–1279.
Harari. Four good photographs on plate 1403, volume 6.
Rep. épig. arabe, 13: no. 4699 reproduces inscription.
Hartner [1950], 190.
Hartner [1955], 8, photograph.
Fiorini, 37.
Stevenson, 1:30–31, and photograph in figure 14.
Destombes [1957], 320 no. 6, where he estimates a date of AD 1304 assuming the maker used a value of 1° per 66 years, as did al-Ṣūfī, for the precession, or at AD 1310 if he used 1° per 70 years as advocated by Nāṣir al-Dīn al-Ṭūsī, founder of the Marāgha observatory.
Mayer [1956], 72–73; says merely last third of thirteenth century.
Needham, 382, and photograph in figure 174, plate LIX.
Maddison & Turner, 79.
Grötzsch, plates 108 and 109.
Zick-Nissen, plates 47 figure 4, 49 figure 3, 50 figure 5.

6.

Location: Paris. Musée du Louvre, Section Islamique; Inventory No. 6013.
Date: 684 [H] [AD 1285–1286].
Maker: Muḥammad ibn Maḥmūd al-Ṭabarī.

Metal; no seam observable; two plugs observed; rattles slightly. Diameter 130 mm. Full set of constellation figures with about 1024 stars indicated by inlaid silver points. Ecliptic latitude circles. Ecliptic and equator graduated by single degrees with every fifth labeled; ecliptic repeats every 30°; equator beginning at vernal equinox has three segments of 100° and one of 60°. Zodiacal names engraved along ecliptic; constellations and many stars labeled; Kūfic. The mak-

er's name is given near the north pole: "The work of (*ṣanʿat*) Muḥammad ibn Maḥmūd al-Ṭabarī." A second inscription near the south equatorial pole reads: "These stars were placed (*rusimat*) according to the *Book of Constellations* [written] by Abū al-Ḥusayn al-Ṣūfī after increasing their longitudes 5° [to] our epoch, while the correction of whatever errors occur and the production of variant readings* [is left] to those who are expert in language†, and that is in the year 684. Inscriptions‡ of Muḥammad ibn Maḥmūd al-Asturlābī."

The globe has holes bored at the ecliptic poles as well as the equatorial poles. The Kūfic script is not very angular and at times tends toward *naskhī*. The great circles wobble slightly and the graduations are uneven. The crossing of the equator and ecliptic at the equinoxes is poorly executed. The stars themselves are so poorly positioned on the globe that the epoch to which they conform varies from the tenth to the sixteenth century AD. It appears that the stars were positioned after the constellation outlines were engraved. The constellations, however, are quite nicely engraved. The imprecision suggests that the globe was not made by a professional instrument maker, despite the maker signing himself as an astrolabe maker. This globe is outstandingly attractive visually, but is in fact imprecise and technically non-functional.

An eight-lobed base with center cross pieces supports four legs (which are clearly modern) attached by screws to the horizon ring. Four 90° arcs are attached to the base and meet to form a pedestal support for the meridian ring and a semicircular arc supporting the horizon ring. The horizon ring is graduated by 2° intervals with every tenth labeled; the numbering repeats every 90° proceeding clockwise. The meridian ring is ungraduated on the east side, as presently mounted, but graduated by 2° intervals on the other, in non-consecutive segments of 90° beginning at the points opposite the celestial equator and ending at the pole. Two of the 90° arcs attached to the base are graduated by 5° intervals with each labeled in Kūfic *abjad* letters from the top of the arc. Two gnomons are attached to two of the semicircular arcs supporting the globe, but the gnomons are not aligned over the graduated arcs as one would expect. The general design of the stand is strikingly similar to No. 3 (made in AD 1225–1226), except that the gnomons are not aligned properly (a failure of the maker to realize the function of the gnomons, or perhaps a poor job of repairing the globe). While the alloy, finish, and engraving of the stand seem to be contemporary with that of the globe, the construction of the stand seems rather recent, which might be due to the stand having been severely and incorrectly repaired and reconstructed in recent times.

See Figure 6 for an illustration.

The globe was acquired by the Mission Archéologique Française in Cairo and since 1892 has been in the Louvre. From June to August 1971 it was exhibited in the "Arts de l'Islam des origines à 1700 dans les collections publiques françaises" at the Orangerie des Tuileries in Paris.

Citations

Casanova. A detailed study of the terminology on the globe; contains no reproduction of the globe
Harari, 5:2518.
Rep. épig. arabe, 13: no. 4864; reproduces inscription.
Destombes [1957], 316 photograph; 320 no. 5, discussion, where maker is listed as Muḥammad ibn Muḥammad al-Aṣṭurlābī.
Destombes [1958], 307, where maker given as Muḥammad ibn Muḥammad ibn ʿAlī al-Ṭabarī.
Mayer [1956], 72.
Orangerie des Tuileries, plate 190; text p. 42.
Sabra [1976], 194, photograph.

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* Reads *taṣḥīf*, meaning "the misplacement of diacritical points" or "the production of alternative readings."

† Reading *mutarjamīn*; or one could read *mutaraḥḥimīn* (omitting the diacritical point) meaning "those who are sympathetic or understanding." Casanova (319) prefers the latter reading.

‡ Reads *kutub*, in the sense of inscriptions; see Dozy 2: 450.

7.

Location: Oxford. Museum of the History of Science, Lewis Evans Collection; Inventory No. 2900.

Date: 764 H [AD 1362–1363], 732 Yazdijird, and 1674 Alexandrian era.

Maker: Jaʿfar ibn ʿUmar ibn Dawlatshāh al-Kirmanī.

Metal; hemispheres joined at equator with soldering evident along seam. Diameter 165 mm; weight 1814.4 gr. Full set of constellation figures with about 1025 stars indicated by inlaid silver points with a depression in the center of each. Ecliptic latitude circles. Ecliptic is graduated by single degrees with no numbering; equator is graduated by single degrees with every fifth labeled in three segments of 100° and one of 60°. Zodiacal names engraved along ecliptic; ecliptic and equatorial poles, constellations and about 50 stars labeled; Kūfic. Holes have been drilled at the equatorial poles, the ecliptic poles and at a position as far from the equatorial poles as the ecliptic poles, but in the opposite direction along the solstitial colure (the purpose of the latter holes is unknown). A removeable pin has been inserted at both the northern and southern ecliptic poles. The Kūfic inscription beneath the Southern Fish reads: "The stars were placed (*rusimat*) according to the *Book of Constellations* [written] by Abū al-Ḥusayn ᶜAbd al-Raḥmān al-Ṣūfī after increasing their longitudes by 6°3′ to our time in the year 764 H, 732 Yazdijird, and 1674 of the Alexandrian era. The work of (*ṣanᶜat*) Jaᶜfar ibn ᶜUmar ibn Dawlatshāh al-Kirmanī." The inscription is engraved over an older, rubbed out inscription, which seems to record that the globe was made by Jaᶜfar for a patron named Muḥammad ibn Aṣīl.

There is a quadruped metal stand supporting two semicircular arcs holding a horizon ring bearing the four cardinal points near the outside edge; the ring is graduated by single degrees with every fifth labeled in non-consecutive segments of 90° beginning at the east-west points and ending at the north-south points where there are notches. The stand, which seems to be original with the globe, is curious in that it allows no room for a meridian ring, which is usually an integral part of a complete celestial globe with stand. There are notches at the north-south points, but not of a size to accommodate a regular meridian ring, for the semicircular metal arc attached to the underside of the horizon ring at the north-south points will not permit a ring to pass through the notches. This semicircular arc essentially serves to mark the nadir of the meridian ring and has a series of holes at 10° intervals for the insertion of a pin. Thus if the moveable pin at the south ecliptic pole were to be placed in the equatorial southern pole of the globe it could then be inserted in one of the holes of this semicircular arc and the globe thus adjusted to different terrestrial latitudes by 10° increments. Perhaps a semicircular arc (now lost) was intended to be placed over the globe and inserted into the notches at the north-south points to serve as the top of the meridian ring and yet be removable to allow readjustment of the globe.

See Figure 9 for an illustration.

Bought by Lewis Evans in 1922 from Percy Webster of London. Exhibited at the exhibition "Science and Technology in Islam" held at the Science Museum, London, as part of the Festival of the World of Islam, April–August 1976.

Citations

Gunther [1923], 2:247–249, with a photograph between pp. 248 and 249. Lists the stars labeled on globe; does not mention older inscription.
Mayer [1956], 53; with photograph of inscription in plate XI.
Destombes [1957], 321 no. 9.
Destombes [1960], 205–206; gives inscription.
Maddison [1961], photograph plate 153B.
Harari, 5:2518.
Muris & Saarmann, 38.
Ghirshman *et al.*, 135; large color photograph. No location or source is given. Plate is labeled "Persian celestial globe, with stars inlaid in silver dated 764." Photograph is printed as a mirror image.
Nasr [1976], 123, plate 80. Labeled as a spherical astrolabe, on the plate; correction given in acknowledgements.
Maddison & Turner, 80.

8.

Location: Istanbul. Kandilli Observatory, History of Science Museum; Inventory No. 763.
Date: 785 H [AD 1383–1384].
Maker: Jaᶜfar ibn ᶜUmar ibn Dawlatshāh al-Kirmānī.

Metal; hemispheres joined at equator. A band of metal of a different alloy has been placed along the seam, with irregular hatch-marks or graduations (probably added later, for the graduations elsewhere on the globe are quite precise). Diameter 114.3 mm. Full set of constellation figures with about 1025 stars indicated by inlaid silver

points with a depression in the center of each, differing in size apparently according to magnitude. Ecliptic latitude circles. Ecliptic is graduated by single degrees with no numbering; equator is graduated by single degrees with every fifth labeled, in three segments of 100° and one of 60°. Zodiacal names engraved along ecliptic; ecliptic and equatorial poles, constellations and about 50 stars labeled; Kūfic. Holes have been drilled at the equatorial poles, the ecliptic poles and at a position as far from the equatorial poles as the ecliptic poles, but in the opposite direction along the solstitial colure (the purpose of the latter holes is unknown). The inscription beneath the Southern Fish reads: "These stars were placed (*rusimat*) with an increase of 6° [lacuna] minutes according to [the Book of] *the Constellations* [by] ᶜAbū al-Ḥusayn ᶜAbd al-Raḥmān al-Ṣūfī in the year 785 H. The work of (*ṣanᶜat*) Jaᶜfar ibn ᶜUmar ibn Dawlatshāh al-Kirmanī."

The increment ought to read 6°23′ to give a value for the precession equivalent to that employed by the maker of the previous globe (No. 7) and by his son (globe No. 62). This globe is identical in nearly every respect to globe No. 7.

Stand and rings missing.

Entry based on published descriptions and photographs.

Citations

Destombes [1960], 206 note 2; gives inscription.
Dizer & Meyer; present six photographs.

9.

Location: Paris. Bibliothèque Nationale, Département des Cartes et Plans; Inventory No. Ge.A.326.
Date: 981 H and 952 Yazdijird [AD 1573–1574].
Maker: Jamāl al-Dīn Muḥammad [ibn] . . . al-Dīn Muḥammad al-Hāshimī al-Makkī.

Metal; appears to be seamless; no seam observable from inside or outside and four possible plugs visible of same alloy; the signature is damaged by a plug of lead 14 × 17 mm and a rectangular hole 13 × 16 mm. Diameter of globe 150 mm; wall thickness 2.5 mm; weight 850 grams. Full set of constellation figures rather poorly drawn. About 900 stars indicated by large silver inlaid points, quite poorly and inaccurately placed. Ecliptic latitude circles. Ecliptic graduated into unlabeled irregular intervals; equator graduated also into irregular intervals with every fifth, more or less, indicated by a longer line and labeled. Zodiacal names engraved along ecliptic; constellations and some stars labeled; *naskhī*. Stars appear to have been added after constellation outlines engraved. Has no holes at equatorial poles. There is a cord at the north ecliptic pole by which it could be suspended. The inscription beneath the Southern Fish in crude *naskhī* is badly damaged by a large rectangular hole and a plug of lead. It appears to read: "Here is the work (*ᶜamal*) of the least [of the servants] . . . al-Aᶜazz Jamāl al-Dīn Muḥammad [ibn]. Dīn Muḥammad al-Hāshimī by ancestry (*nasaban*), al-Makkī by birth (*mawlidan*) . . . in the most noble of cities . . . may [God] increase its greatness . . . with high esteem and honor in the year 981 H and 952 Yazdijird."

Stand and rings missing.

Entry based on photograph supplied by A. Brieux and F.R. Maddison, published accounts, and information obtained from M. Destombes and A.J. Turner.

Formerly in the collection of M. le Comte de Viel Castel; acquired by Bibliothèque Nationale in 1857. Exhibited in Paris at the UNESCO exhibition "L'Islam et les Sciences," 8–21 July 1981.

Citations

Vallée, 47 no. 292.
Stevenson, I: fig. 15, opposite p. 33. States globe is by Diemat Eddin Mohammed and dated 981 H/AD 1573, information furnished him by Vallée. This is apparently an attempt to attribute it to Ḍiyāʾ al-Dīn Muḥammad of Lahore of the seventeenth century.
Fiorini, 47. Here it is also attributed to Diemat-Eddin-Mohammad.
Muris & Saarmann, 38; again gives maker as Diemat Eddin Mohammad.
Mayer [1956], 73; gives correct maker.

10.

Location: London. Private collection.
Date: 998 [H] and thirty-fourth year of reign of Akbar [AD 1589–1590].
Maker: *ᶜAlī Kashmīrī ibn Lūqmān.*

Metal; no seam observable; four small round plugs visible in southern hemisphere. Diameter unknown. Full set of constellation figures with about 1018 stars indicated by inlaid silver points. Ecliptic latitude circles. Ecliptic and equator indicated by single lines on which are small dots at 2° intervals without numbering. Zodiacal names are engraved along ecliptic in small inconspicuous labels and do not extend to the width of each house as is customary. Constellations, equinoxes, solstitial colure, equatorial poles, and major stars labeled; *naskhī* tending toward *ta*ᶜ*līq*, written without diacritical points. Beneath the Southern Fish is an inscription in Arabic without diacritical points which seems to read: "The one in need of God the Merciful, ᶜAlī Kashmīrī ibn Lūqmān, [in] the year 998 corresponding to 34 [of the reign] of Akbar affixed to the globe the observable stars after the calculation of their position (*taqwīm*), and he made it (*ṣana*ᶜ*ahā*) in a manner useful for the knowledge of all the requirements of astrolabe makers, as an *aide-mémoire* to their craft."

The word for "of Akbar" (*Akbarī*) is not at all clear on the globe, but if the year 998 is interpreted as a Hijrah date, then the thirty-fourth year of Akbar's reign would correspond as stated.

Stand and rings missing.

See Figures 11 and 69 for illustrations.

Entry based on photographs in the files of A. Brieux and F.R. Maddison.

11.

Location: Stonyhurst College Library near Blackburn, Lancashire, England.

Date: The eighteenth year of the reign of Jahāngīr [AD 1622–1623].

Maker: Qāʾim Muḥammad ibn ᶜĪsà ibn Allāhdād Asṭurlābī Lāhūrī Humāyūnī.

Metal; no seam observable; three plugs observed including one large round one near inscription; rattles. Diameter 188 mm. Full set of constellation figures with about 1018 stars indicated by inlaid silver points. Ecliptic latitude circles. Ecliptic and equator graduated by single degrees, with every fifth labeled; both ecliptic and equator are continuously numbered from 5° to 360°, but the ecliptic bears an additional numbering of 5 to 30, repeated for 12 segments. Zodiacal names engraved along ecliptic; the names of the 28 lunar mansions are also engraved along ecliptic on opposite side from zodiacal names; Constellations, celestial poles, and major stars labeled; *naskhī*. Between the two south poles and the end of Eridanus an inscription in Arabic reads: "Its owner (*ṣāḥibuhu*) is Nawāb (His Excellency, Iᶜtiqād Khān. The eighteenth year of the reign of Jahāngīr." Beneath in the same hand it reads "The work of (*ṣan*ᶜ*at*) the least of the servants (*aqall al-*ᶜ*ibād*) Qāʾim Muḥammad ibn ᶜĪsà ibn Allāhdād Asṭurlābī Lāhūrī Humāyūnī."

The ungraduated metal meridian ring and the wooden pedestal stand on which it is mounted are of very recent origin.

See Figures 12, 13, 37, 41, and 46 for illustrations.

Acquired in Lucknow in 1858.

12.

Location: Paris. Private collection.

Date: 1035 H and the twenty-first year of the reign of Jahāngīr [AD 1625–1626].

Maker: Qāʾim Muḥammad ibn ᶜĪsà ibn Allāhdād Asṭurlābī Lāhūrī Humāyūnī.

Metal; no seam observable; one round plug is missing from globe in the constellations of Aquilla and Serpens (see Figure 36 for illustration). Diameter unknown. Full set of constellation figures with about 1018 stars indicated by inlaid silver points. Ecliptic latitude circles. Ecliptic and equator graduated by single degrees with every fifth labeled; equator numbered continuously from vernal equinox, while ecliptic repeats every 30°. Zodiacal names engraved along ecliptic; the names of the 28 lunar mansions are also engraved along ecliptic on opposite side from zodiacal names; constellations, celestial poles and major stars labeled; *naskhī*. Around the two southern poles is written the following inscription: "The year 1035 H. Work of (*ṣan*ᶜ*at*) the least of the servants Qāʾim Muḥammad ibn ᶜĪsà ibn Allāhdād Asṭurlābī Lāhūrī Humāyūnī. The twenty-first year of the reign of Jahāngīr."

The ungraduated horizon ring with quad-

ruped stand on ring base is a recent replacement. Meridian ring missing. The globe has been mounted by a pin passing through the celestial poles and fixed horizontally to the horizon ring.

Formerly in the collection of Bahari in Teheran.

Entry based on photographs in the files of A. Brieux and F.R. Maddison.

13.

Location: London. The Victoria and Albert Museum, Department of Metalwork; Inventory No. M.828-1928. Marling Gift.

Date: The twenty-second year of the reign of Jahāngīr [AD 1626–1627].

Maker: Qā᾿im Muḥammad ibn ᶜĪsà ibn Allāhdād Aṣṭurlābī Lāhūrī Humāyūnī.

Metal; no seam observable; one obvious round plug. Diameter 156 mm. Full set of constellation figures with about 1018 stars indicated by inlaid silver points. Ecliptic latitude circles. Ecliptic and equator graduated by single degrees with every fifth labeled; ecliptic repeats every 30°, while equator is numbered continuously from vernal equinox. Zodiacal names engraved along ecliptic; constellations, celestial poles, and major stars labeled; *naskhī*. Signature is inscribed near southern ecliptic pole: "The work of the least of the servants (*ṣanᶜat aqall al-ᶜibād*) Qā᾿im Muḥammad ibn ᶜĪsà ibn Allāhdād Aṣṭurlābī Lāhūrī Humāyūnī." Near the end of Eridanus the date is given: "Twenty-second year of the reign of Jahāngīr."

Has a metal quadruped stand on circular base with central support; horizon ring graduated by single degrees with every fifth labeled, with the four cardinal points, and the four intermediate ones, engraved near outer edge; the ring is numbered in non-consecutive 90° segments, beginning at the east-west points and terminating at the north-south points where there are notches for the meridian ring. Ungraduated recent meridian ring. There are also notches at the east-west points of the horizon ring which may have been for a semicircular ring (now missing) over the top to mark the zenith and serve as the prime vertical.

See Figures 38 and 42 for illustrations.

14.

Location: Patna (Bihar), India. Khuda Bakhsh Oriental Public Library; Inventory No. 1127.

Date: 1047 H [AD 1637–1638].

Maker: Qā᾿im Muḥammad ibn ᶜĪsà ibn Allāhdād Aṣṭurlābī Lāhūrī Humāyūnī.

Metal with silver inlaid stars. The inscription giving the maker reads: "The work of (*ṣanᶜat*) the least of the servants Qā᾿im Muḥammad ibn ᶜĪsà ibn Allāhdād Aṣṭurlābī Lāhūrī Humāyūnī [in the] year 1047 H." A second inscription in Persian on the globe reads:

> The whole of this complete globe contains 1022 stars, all of which scholars and astronomers have observed to be 48 constellations, just as has been observed also in the observatory of Mirzā Ulugh Bēg, and we have added 3 degrees to the position (*taqwīm*) of each fixed star, according to the calculations of the scholars and wise men of this science, up to this date, the year 1047 H.

This inscription displays elements of the eastern form of Persian spoken outside of Persia proper, and probably a form of Persian called *Tājīk* (see Barthold *EI*).

No further information available; no photograph or drawing has been published. Entry based on published accounts.

Citations

Nadvi [1935], 627 gives the two inscriptions.
Klüber, 5.
Wiet ([1936], 98, no. 5).

15.

Location: Kuwait, private collection.

Date: 1049 H [AD 1639–1640].

Maker: Muḥammad Muqīm ibn ᶜĪsà ibn Allāhdād Aṣṭurlābī Humāyūnī Lāhūrī.

Metal; no seam observable; rectangular plug near south ecliptic pole. Diameter unknown. Full set of constellation figures with about 1018 stars indicated by inalid silver points. Ecliptic latitude circles. Stars are numbered within a constellation. Major stars labeled; *naskhī*. Near the end of Eridanus the inscription reads: "The work of (*ṣanᶜat*) of the weakest of the servants (*aḍᶜaf al-ᶜibād*) Muḥammad Muqīm ibn ᶜĪsà ibn Allāhdād Aṣṭurlābī Humāyūnī Lāhūrī in the year 1049 H."

No further information available. Entry based

on photograph in the files of A. Brieux and F.R. Maddison.

16.

Location: London. The Victoria and Albert Museum, Department of Metalwork; Inventory No. M. 827-1928.
Date: 1050 [H] [AD 1640–1641].
Maker: Muḥammad Zamān.

Metal; hemispheres joined at equator. Diameter 179 mm. Full set of constellation figures with about 1018 stars indicated by very small inlaid silver points. Ecliptic latitude circles; equatorial tropic circles and ecliptic polar circles; equinoctial colure. Equator and ecliptic graduated by single degrees with every sixth labeled; ecliptic repeats every 30°, while the equator is numbered continuously from the vernal equinox. Solstitial colure graduated by single degrees with every sixth indicated by a slightly longer line. Zodiacal names in small writing engraved along ecliptic; constellations, equatorial and ecliptic poles and many stars labeled; small cursive *naskhī*. The inscription in Arabic between the two southern poles reads: "The work of (*ṣanᶜat*) the dust of the threshold of Riẓā (*turāb ᶜatabat al-riẓā*) Muḥammad Zamān, 1050." The reference is to the sanctuary of the Imām Riẓā in Mashhād, where the maker worked. The date is not entirely clear and can be read as 1051 or 1050. The maker also made a globe without constellations, No. 64.

The quadruped metal stand, possibly contemporary with globe, supports the globe with semicircular metal arcs and has an horizon ring graduated by single degrees with every sixth labeled and numbered continuously in a counterclockwise direction; the ring has two notches, one at 90° and one at 270° to accommodate the meridian ring. Meridian ring is missing.

See Figure 21 for an illustration.

Formerly in the collection of Sir Charles Marling, K.C.M.G. Exhibited in the exhibition "Science and Technology in Islam" held at the Science Museum, London, as part of the Festival of the World of Islam, April–August 1976.

Citations

Mayer [1956], 78; reads date as 1051.
Maddison & Turner, 81, read date as 1051.

17.

Location: Kuwait, private collection.
Date: 1054 [H] [AD 1644–1645].
Maker: Muḥammad Zamān.

Metal; seam along equator. Diameter unknown. Full set of constellations figures engraved with about 1018 stars indicated by small inlaid silver points. Ecliptic latitude circles. Equator and ecliptic graduated by single degrees with every fifth indicated by a longer line. The Persian inscription in *naskhī* script reads: "Dust of the road of life (*khāk rah ān*) Muḥammad Zamān 1054."

A modern pedestal stand supports two crossed semicircular bars which hold the horizon ring. The globe has a rod passing through the celestial poles, which is mounted horizontally to the horizon ring. Meridian ring missing.

No further information available. Entry based on photographs in the files of A. Brieux and F.R. Maddison.

18.

Location: New York City. Columbia University, Butler Library, David Eugene Smith Collection; No. 27-198.
Date: 1055 H [AD 1645–1646].
Maker: Ḍiyāᵓ al-Dīn Muḥammad ibn Qāᵓim Muḥammad ibn ᶜĪsà ibn Allāhdād Asṭurlābī Humāyūnī Lāhūrī.

Metal; dark finish; no seam observable; several plugs visible including one quite large oval plug from the Southern Fish to the southern celestial pole and a round one in the northern hemisphere. Diameter 170 mm. Full set of constellation figures engraved with about 1018 stars indicated by small inlaid silver points which have tarnished. Ecliptic latitude circles. Ecliptic and equator graduated by single degrees with every fifth labeled; ecliptic repeats every 30°, while equator is labeled continuously from vernal equinox. Division between the 5° intervals indicated by dotted lines on both ecliptic and equator. Names of zodiacal signs engraved along ecliptic; equatorial poles, constellations and major stars labeled; *naskhī*. The constellations and the individual stars within a constellation are numbered. Near the end of Eridanus is the Persian inscrip-

tion: "This is the work of (*īn ṣanᶜat*) Ḍiyāᵓ al-Dīn Muḥammad ibn Qāᵓim Muḥammad ibn ᶜĪsà ibn Allāhdād Asṭurlābī Humāyūnī Lāhūrī in the year 1055 H."

The heavy three-legged metal stand holds an horizon ring graduated by single degrees with every fifth labeled in non-consecutive segments of 90°, beginning at the two points of the attachment of the semicircular ring over the top of the globe and ending at the two notches for the meridian ring. To the underside of the horizon ring is attached a semicircular arc for supporting the meridian ring and globe. The semicircular ungraduated metal arc over the top of the globe at right angles to the horizon and meridian rings serves to mark the zenith and prime vertical and is hinged at one point of attachment to the horizon ring and held with a pin at the other so that the globe can be removed or readjusted; a small ring is attached as a handle. The meridian ring is graduated along the outside edge by single degrees with every fifth labeled in non-consecutive segments of 90°; the inside edges of the ring are graduated by single degrees. One half of the ring (from zero point to zero point) is twice as thick as the other semicircle. Under the thinner half of the ring there rotates a thin 90° arc graduated by single degrees which is attached at the midpoint, or 90° label, of the thinner half-circle. On the outside edge of the meridian ring at one of the zero points is a protruding lip. Two opposite 90° arcs of the ring contain holes at every 5° interval; the other two opposite quadrants have holes at approximately 18°, 23°, 27°, 32°, and 37°. Thus when set into the stand with the thicker half of the ring below the horizon ring and the protruding lip resting on the horizon ring to hold it steady, the globe can then be rectified for five northern geographical positions. The rotating arc attached at the zenith could be used to measure altitude. It is likely that the holes at every 5° for the southern settings are simply for form. The rod serving as the axis for the globe is missing. The horizon ring has been repaired in many places. Rings appear to be contemporary with globe.

See Figure 15 for an illustration.

Citations

Industrial Museum of New York, 59 (exhibition catalog).
Sanford, 17 (photograph incorrectly said to be of a "Hindu celestial sphere ca. 1590").
Yonge, 84.

19.

Location: Leningrad, Musée asiatique (Muzej antropologii i ètnografii im. Petra Velikogo).
Date: 1057 H [AD 1647–1648].
Maker: Ḍiyāᵓ al-Dīn Muḥammad ibn Qāᵓim Muḥammad ibn ᶜĪsà ibn Allāhdād Asṭurlābī Humāyūnī Lāhūrī.

The signature on globe reads: "This is the work (*īn ṣanᶜat*) of Ḍiyāᵓ al-Dīn Muḥammad ibn Qāᵓim Muḥammad ibn ᶜĪsà ibn Allāhdād Asṭurlābī Humāyūnī Lāhūrī in the year 1057 H."

No further information available; entry based on printed description.

Citations

Khanykov, 66–69; gives the signature and a few star names; no physical description of globe.
Dorn [1865], 1.
Wiet [1935], 98, no. 9.

20.

Location: London. The Victoria and Albert Museum, Department of Metalwork; Inventory No. M.507-1888.
Date: 1060 H [AD 1650].
Maker: Ḍiyāᵓ al-Dīn Muḥammad ibn Qāᵓim Muḥammad Mullā ᶜĪsà ibn Shaykh Allāhdād Asṭurlābī Humāyūnī Lāhūrī.

Metal; no seam observable; two plugs visible, one of a different alloy from rest of globe. Diameter 113 mm. Full set of constellation figures with about 1018 stars indicated by inlaid silver points. Ecliptic latitude circles. Ecliptic and equator graduated by single degrees with every fifth labeled; ecliptic repeats every 30°, while equator is numbered continuously from the vernal equinox; divisions between 5° intervals marked by dotted lines on both ecliptic and equator. Zodiacal names engraved along ecliptic; equatorial poles, constellations and many stars labeled; *naskhī*. Constellations are numbered in order. Inscription near end of Eridanus reads: "The work of (*ᶜamal*) the least of the servants (*aqall al-ᶜibād*)

Ḍiyāʾ al-Dīn Muḥammad ibn Qāʾim Muḥammad Mullā ʾĪsà ibn Shaykh Allāhdād Asṭurlābī Humāyūnī Lāhūrī [in the] year 1060 H."

The quadruped metal stand on a ring base is non-functional in that the top ring cannot serve as a horizon ring; not contemporary with globe. Meridian ring missing. The holes at the equatorial poles of the globe have been filled in; many of the inlaid silver points are now missing.

Citations

Casanova, 318.
Wiet [1935], 17.
Wiet [1933], 60.
Wiet [1936], 98, no. 12.
Klüber, 2.
Harari, 5:2518.

21.

Location: Aligarh, India, Tibbiyah College.
Date: 1064 H [AD 1653–1654].
Maker: Ḍiyāʾ al-Dīn Muḥammad ibn Qāʾim Muḥammad ibn Mullā ʿĪsà ibn Shaykh Allāhdād Asṭurlābī Humāyūnī Lāhūrī.

The inscription reads: "The work of (*ʿamal*) the least of the servants Ḍiyāʾ al-Dīn Muḥammad . . . ."

No further information available.

Citation

Nadvi [1935], 628 no. 4, gives inscription.

22.

Location: London. The Victoria and Albert Museum, Indian Section; Inventory No. 2324-1883 (I.S.).
Date: 1067 H [AD 1656–1657].
Maker: Ḍiyāʾ al-Dīn Muḥammad ibn Qāʾim Muḥammad ibn Mullā ʿĪsà ibn Shaykh Allāhdād Asṭurlābī Humāyūnī Lāhūrī.

Metal; no seam observable; one large round plug visible. Diameter 127 mm. Full set of constellation figures and about 1018 stars indicated by inlaid silver points. Ecliptic latitude circles; equatorial tropic circles. Ecliptic and equator graduated by single degrees with every fifth labeled; ecliptic repeats every 30° while equator is numbered continuously from the vernal equinox. The divisions between the 5° intervals are indicated by dotted lines on both equator and ecliptic. Zodiacal names engraved along ecliptic; constellations and many stars labeled; *naskhī*. Constellations are numbered in order. Signature reads: "Work of (*ʿamal*) the least of the servants Ḍiyaʾ al-Dīn Muḥammad . . . "

Stand and rings missing.

The globe was purchased in Bombay in 1882 and was part of the India Museum which was formerly located where now the Imperial College of Science is in London. The entire collection of the India Museum was transferred to the Indian Section of the Victoria and Albert Museum. In 1974 the globe was in a traveling exhibit from the Victoria and Albert.

Citations

Casanova, 318.
Wiet [1933], 60.
Wiet [1935], 17.
Wiet [1936], 99 no. 16.
Gunther *AW*, 1:210.
Klüber, 2 and 5.

23.

Location: Cardiff. Welsh Industrial and Maritime Museum, Amgueddfa Diwydiant a Môr Cymru; Inventory No. 39.573.1.
Date: 1068 H and the thirty-second year of the reign of Shāh Jahān [AD 1657–1658].
Maker: Ḍiyāʾ al-Dīn Muḥammad ibn Qāʾim Muḥammad ibn Mullā ʿĪsà ibn Shaykh Allāhdād Asṭurlābī Humāyūnī Lāhūrī

Metal; no seam observable; one visible plug; rattles; biased in weight. Diameter 113 mm. Full set of constellation figures with about 1018 stars indicated by small inlaid silver points. Ecliptic latitude circles; equatorial tropic circles and equatorial polar circles. Equator and ecliptic graduated by single degrees with every fifth labeled; ecliptic repeats every 30°, while equator is numbered continuously from the vernal equinox. Divisions between every 5° interval indicated by dotted lines on both ecliptic and equator. Zodiacal names engraved along ecliptic; equatorial poles, constellations and many stars labeled; *naskhī*. Constellations are numbered; in-

dividual stars are numbered within some of the northern constellations. The inscription around the south equatorial polar circle reads: "The work of (ᶜ*amal*) the least of the servants Ḍiyāʾ al-Dīn . . . . [in the] year 1068 H, the thirty-second year of the blessed reign (*julūs mubārak*) of Shāh Jahān."

The metal pedestal stand on a circular base with two crossing semicircular arcs holding a ring is non-functional in that the ring cannot serve as a horizon ring; the stand was made by Newton & Co., 3 Fleet Street, London. The meridian ring, which is graduated by 5° with every 30° interval indicated by a longer line, is also probably not contemporary with the globe.

See Figures 39, 44, and 48 for illustrations.

Bought in Algiers in 1910 and given by donor to museum in 1939.

24.

Location: Cairo. Museum of Islamic Art; Inventory No. 15226.

Date: [10]68 H and thirty-second year of reign of Shāh Jahān [AD 1657–1658].

Maker: [Ḍi]yāʾ al-Dīn Muḥammad ibn Qāʾim Muḥammad ibn Mullā ᶜĪsà ibn Shaykh Allāhdād Asṭurlābī Humāyūnī Lāhūrī.

Metal; no seam observable; one rectangular plug and one very large plug constituting nearly one-fourth of the globe. Diameter 100 mm. Full set of constellation figures with about 1018 stars indicated by small inlaid silver points. Ecliptic latitude circles; southern celestial polar circle. Holes at both ecliptic and celestial poles. Equator and ecliptic graduated by single degrees with every fifth labeled; ecliptic repeats every 30° while equator is numbered continuously from vernal equinox. Division between every 5° interval indicated by dotted line on both ecliptic and equator. Zodiacal names engraved along ecliptic; equatorial poles, constellations and major stars labeled; *naskhī*. The inscription around the south equatorial polar circle reads: "The work of (ᶜ*amal*) the least of the servants [Ḍi]yāʾ al-Dīn Muḥammad . . . . in the year [10]68 [H] and the thirty-second year of the blessed [reign] of Shāh Jahān." The plugs interfere with the inscription.

Metal horizon ring supported by a metal quadruped stand, 137 mm high on ring base with semicircular undersupport for globe. Probably not contemporary with globe. Meridian ring missing.

Formerly Harari Collection, No. 157.

Citations

Wiet [1933], 60.

Wiet [1935], 16–17, no. 36, gives inscription in slightly variant form.

25.

Location: New Delhi, India. Red Fort Archaeological Museum; Inventory No. 40–415.

Date: 1070 [H] [AD 1659–1660].

Maker: Muḥammad Ṣāliḥ Tatahwī [*sic*].

Metal; no seam or plug observed in available photographs. Diameter 210 mm. Full set of constellation figures with about 1018 stars indicated by silver inlaid points. Ecliptic latitude circles. Holes at both ecliptic and celestial poles. Graduation of equator and ecliptic not evident from photographs. Equatorial and ecliptic poles, ecliptic latitude circles, constellations, and major stars labeled; *naskhī*. Near the south ecliptic pole is the inscription reading: "By the order of (*bi-farmāyish*) Shaykh ᶜAbd al-Khāliq. The work of (ᶜ*amal*) Muḥammad Ṣāliḥ Tatahwī [in the] year 1070."

The name of the maker, Tatahwī (perhaps more accurately transliterated as Tatah-wī) is written differently on this globe than on globe No. 29, where it is spelled Tatawī. By writing it as Tatah-wī, though it is unusual orthography, the maker probably wished to indicate the pronunciation, for one might be inclined to pronounce it as Tatwī with the spelling on globe No. 29. It is unlikely that the maker was from Tatta in the Sind (the delta of the Indus river) since the name of the town is written with slightly different letters and should more accurately be transliterated as Thaṭṭhā. The globe itself displays basically Mughal design of constellation figures and exhibits considerable precision in design.

In the one published photograph a rod passes through the globe by which it is mounted hori-

zontally to a stand that is 660 mm high. The stand is clearly non-functional and probably not contemporary with globe.

Entry based on the published account and two photographs in the files of A. Brieux and F.R. Maddison.

Citations

Dhama, 143–144, plate LVIII.
Stone, 160.

26.

Location: Berlin. Staatliche Museum zu Berlin, DDR; Inventory No. 1101.

Date: 1071 H [AD 1660–1661].

Maker: Ḍiyāʾ al-Dīn Muḥammad ibn Muḥammad [Qāʾim] Muḥammad ibn Mullā ʿĪsà ibn Shaykh Allāhdād Asṭurlābī Humāyūnī Lāhūrī.

Metal; no seam observable; one plug visible. Diameter 94 mm; wall thickness ca. 3 mm. Full set of constellation figures with about 1018 stars indicated by inlaid silver points. Ecliptic latitude circles; equatorial tropic and polar circles. Ecliptic and equator graduated by single degrees with every sixth labeled; ecliptic repeats every 30°, while equator is numbered continuously from the vernal equinox. Divisions between 6° intervals indicated by dotted lines. Names of zodiacal houses engraved along ecliptic; constellations, equatorial poles, and some stars labeled; *naskhī*. Constellations numbered in order. Inscription near south equatorial pole begins "The work of (*ʿamal*) the least of the servants Ḍiyāʾ al-Dīn Muḥammad . . . ." The word Qāʾim has been defaced and the preceding Muḥammad added in its place.

See Figure 45 for an illustration.

Stand and rings are missing.

Citations

Klüber. A lengthy study of the globe with two photographs and several lithograph reproductions.
Nadvi [1935], 629, no. 5.

27.

Location: Edinburgh. Royal Scottish Museum, Department of Technology; Inventory No. 1890-331 (Richard Collection).

Date: 1074 H [AD 1663–1664].

Maker: Ḍiyāʾ al-Dīn Muḥammad ibn Qāʾim Muḥammad ibn Mullā ʿĪsà ibn Shaykh Allāhdād Asṭurlābī Humāyūnī Lāhūrī.

Metal; no seam observable; three plugs visible. Diameter 142 mm. Full set of constellation figures with about 1018 stars indicated by inlaid silver points. Ecliptic latitude circles; equatorial polar circles; equatorial tropic circles lightly engraved. Ecliptic and equator graduated by single degrees with every fifth labeled; ecliptic repeats every 30° while equator is numbered continuously from the vernal equinox. Divisions between 5° intervals indicated by dotted lines. Names of zodiacal signs engraved along ecliptic; equatorial poles, constellations, and many stars labeled; *naskhī*. Constellations are numbered in order. Inscription around southern equatorial pole begins: "The work of (*ʿamal*) the least of the servants Ḍiyāʾ al-Dīn Muḥammad . . . ."

The quadruped metal stand on circular base (height 170 mm) with central support has an horizon ring graduated by single degrees with every fifth labeled and bearing the four cardinal points near outer edge of ring. Horizon ring is numbered in non-consecutive segments of 90° beginning at the east-west points and ending at the north-south points. The ring has notches at the north-south points for the meridian ring and also notches at the east-west points, possibly for a semicircular ring over the top (now missing) to mark the zenith and prime vertical. Ungraduated meridian ring, but with holes for adjustment for six different terrestrial latitudes. Horizon ring appears to be of same alloy as globe and hence possibly contemporary with globe.

See Figures 16 and 35 for illustrations.

Bought in 1890 from F. Du Cane Godman after being shown in the Richard Collection at the Paris Exhibition of 1889. In 1931 it was exhibited at the International Exhibition of Persian Art at the Royal Academy of Arts in London. Exhibited at the exhibition "Science and Technology in Islam" held at the Science Museum, London, as part of the Festival of the World of Islam, April–August 1976. Displayed at the exhibition "Science in India" held at the

Science Museum, London, March-August 1982. Commonly called the "Barlow Globe."

Citations

Photograph, *Illustrated London News*, December, 1930, p. 1025.

Exhibition catalog of the "International Exhibition of Persian Art at the Royal Academy of Arts, London, 1931." In the first edition it was stated that it belonged to Mr. Barlow (no. 309A), hence the name "Barlow globe." In second edition, described on p. 175 (no. 309B); and in third edition, on p. 193 (no. 309B).

Wiet [1933], 59–60, no. 58, and 139, where it is incorrectly said to be part of the Harari collection.

Wiet [1935], 17.

Wiet [1936], 99 no. 24.

Nadvi [1935], 629 where it is stated to be an astrolabe.

Maddison & Turner, 82.

Anderson, 34, no. 124

28.

Location: Oxford. Museum of the History of Science, Billmeir Collection; Inventory No. 57-84/25.

Date: 1074 H [AD 1663–1664].

Maker: Ḍiyāʾ al-Dīn Muḥammad ibn Qāʾim Muḥammad ibn Mullā ʿĪsà ibn Shaykh Allāhdād Aṣṭurlābī Humāyūnī Lāhūrī.

Metal; no seam observable; two plugs observed; has a rather dull black finish. Diameter 175 mm; weight 2097.9 grams, including meridian ring. Full set of constellation figures with about 1018 stars indicated by inlaid silver points. Ecliptic latitude circles; equatorial polar circles. Equator and ecliptic graduated by single degrees with every fifth labeled; ecliptic repeats every 30° while equator is numbered continously from the vernal equinox. Division between every 5° interval indicated by dotted lines. Zodiacal names engraved along ecliptic; equatorial poles, constellations and many stars labeled; *naskhī*. Constellations numbered in order. Inscription around south equatorial polar circle begins; "The work of (*ʿamal*) the least of the servants Ḍiyāʾ al-Dīn Muḥammad . . . ."

Inside the sphere there are three rolled-up pieces of paper with writing on them (amulets ?) which have been sewn together with twine, and also a rather long heavy metal probe, pencil shaped, around which the papers appear to have been rolled. The diameter of the probe is greater than that of the holes in the globe at the poles. Therefore, it must have been inserted, along with the papers, before the final plug was put in place on the globe.

The metal three-legged heavy stand has an horizon ring graduated by single degrees and labeled every 5° in non-consecutive segments of 90° converging at the two notches for the meridian ring; may be contemporary with the globe and is quite similar to that of globe No. 18. A semicircular arc attached to the underside of the horizon ring supports the ungraduated meridian ring which is a later replacement.

See Figures 40, 43, and 47 for illustrations.

Formerly in the M. Henri Michel Collection.

Citation

Josten, 20, no. 25; and photograph in plate VII.

29.

Location: London. Private collection.

Date: 1074 [H] [AD 1663–1664].

Maker: Muḥammad Ṣāliḥ Tatawī.

Metal; no seam observable; large figure-eight plug near north ecliptic pole. Diameter unknown. Full set of constellation figures with about 1018 stars indicated by inlaid silver points. Ecliptic latitude circles; equatorial tropic circles. Ecliptic graduated by single degrees with every fifth labeled in both Arabic and in Sanskrit (Devanāgarī characters); both sets of numerals are written alongside each other and repeat every 30°. The equator is graduated by single degrees with every fifth labeled in Arabic (*abjad* numerals) on one side and every sixth labeled in Sanskrit (Devenāgarī characters) on the opposite side; numbering is continuous from the vernal equinox. Names of zodiacal houses written along ecliptic in fairly small script, not extended to the width of each house, in both Sanskrit and Arabic, using the word *burj* in Arabic for zodiacal house. Ecliptic latitude circles, tropics, ecliptic poles, the *mayl kullī*, constellations, and major stars labeled in Arabic, and the constellation names and signature inscription are also inscribed in Sanskrit.

The script is very precise and clear; *naskhī* and Devanāgarī. The constellations are carefully and attractively executed in Mughal style; precision and uniformity good. Inscription beneath Southern Fish reads: "The work of (*ᶜamal*) Muḥammad Ṣāliḥ Tatawī [in the] year 1074." There is also a Sanskrit inscription. See globe No. 25 for another globe by this maker, on which he spells his name with a slight variation.

Metal quadruped stand with spindle shaped legs is on a base formed of two cross bars. Horizon ring is graduated by single degrees with every sixth labeled in Devanāgarī characters in non-consecutive segments of 90° converging at the two notches for the meridian ring. Attached to the underside of the horizon ring is a semicircular bar, with a finial at the bottom, which supports a modern ungraduated meridian ring. The horizon ring and stand appear to be contemporary with globe.

See Figure 18 for an illustration.

Formerly in collection of Alain Brieux of Paris.

Entry based on photographs in the files of A. Brieux and F.R. Maddison.

30.

Location: Paris. Private collection.
Date: 1090 H [AD 1679–1680].
Maker: Ḍiyāᵓ al-Dīn Muḥammad ibn Mullā Qāᵓim Muḥammad ibn Ḥāfiẓ ᶜĪsà ibn Shaykh Allāh-dād Humāyūnī.

This is not really a globe, but an open, cut-out sphere consisting of two raised or hammered hemispheres in which spaces between the constellation outlines and great circles have been cut out or worked *à jour*. The hemispheres are easily separated and meet along the circle of the equator. Metal, covered with gilt paint and varnish; has been repaired in places. The gilt finish, covered with varnish, is also inside the sphere where it has not worn off, as it has on many areas of the outside surface. Diameter 164 mm. Full set of constellation figures, with details engraved on the figures and backgrounds cut out. About 1018 stars indicated by holes perforating the sphere, some of which seem to be filled with glass or mica. Ecliptic latitude circles each about 6 mm wide, and equatorial and ecliptic polar circles. Holes at both ecliptic and equatorial poles. Ecliptic and equator, each about 15 mm wide, are graduated by single degrees with every fifth indicated by a dotted line and labeled; equator numbered continuously from vernal equinox; ecliptic repeats every 30°. Zodiacal names engraved along ecliptic; each ecliptic latitude circle, the poles, equatorial polar circles, constellations, and major stars labeled in a mixture of Arabic and Persian; *naskhī*. The Persian inscription written in five parts around the two southern polar circles reads as follows:

In the reign of His Majesty Muḥyī al-Dīn Muḥammad Aurangzīb Bahādar ᶜĀlamgīr, this sphere was invented (*ikhtirāᶜī*) by order of (*bi-farmāyish*) this excellent nawab, an exalted and publicly esteemed sovereign and learned builder. This invented (*ikhtirāᶜī*) terrestrial-celestial sphere is the work of (*ᶜamal*) the weakest of the servants (*aḍaᶜf al-ᶜibād*) Ḍiyāᵓ al-Dīn Muḥammad ibn Mullā Qāᵓim Muḥammad ibn Ḥāfiẓ ᶜĪsà ibn Shaykh Allāh-dād Humāyūnī in the year 1090 H.

This inscription implies that this sphere, of special design for the Mughal emperor ᶜĀlamgīr I, was both a terrestrial and celestial sphere—hence we may suppose that at one time a small terrestrial globe was placed in it. By having the stars as well as the spaces between the constellations and circles cut out, a sufficient amount of light would be introduced into the sphere to allow inspection of the enclosed terrestrial globe. Thus this celestial sphere seems to have been part of a demonstrational armillary sphere and as such is of a unique design among extant Islamicate instruments. The signature of the maker shows slight differences from his signatures on other globes, notably the different orthography used in writing Allāh-dād, the introduction of the name Ḥāfiẓ, and the omission of Lāhūrī.

Stand and rings missing.

See Figure 17 for an illustration.

Formerly in the collection of Leonard Linton of Point Lookout, New York, before being sold in Paris in 1980.

Citation

Collection of Leonard Linton. Sale: Nouveau Drouot, 9 rue Drouot, 9–10 October 1980. Commissaires-Priseurs: E.

Libert and A. Castor. Expert près les Douanes: A. Brieux (sale catalog). Item No. 185, p. 131, and photograph p. 130.

31.

Location: Leningrad. Lomonosov Museum (Muzej M.V. Lomonosova).

Date: Begun the eleventh day of Shawwāl, 1112 H [21 March AD 1701] with equivalent date given in the Era of the Flood as well as the Coptic, Alexandrian, Yazdijird and Malikshāh eras, and completed in Ṣafar, 1113 H [8 July to 5 August AD 1701].

Maker: Riḍwān.

Metal; hemispheres. Diameter 183 mm. Full set of constellation figures; about 1018 stars indicated by inlaid silver points. Considerable traces of what was once complete gilding are visible. Ecliptic latitude circles; equinoctial colure. Ecliptic and equator graduated by single degrees marked by dots; equator has every fifth degree indicated by a line and labeled with standard (not *abjad*) numerals, numbering continuously from the vernal equinox; ecliptic has every sixth degree indicated by a line with numbering in standard numerals repeating every 30°. Zodiacal names engraved along ecliptic; equatorial and ecliptic poles, constellations and many stars labeled; *naskhī*. Constellations are numbered with standard numerals in order; some individual stars are numbered with *abjad* numerals. Under Eridanus there is a lengthy Arabic inscription, ending with a quotation from the Qurʾān III,167, which reads:

The construction (*ᶜamal*) of this globe was carried out (*kumila*) with the engraving on it of the fixed stars—whose number is 1022—after the adjustment of their longitudes according to the principles of Ulugh Bēg, author of the recent observations at Samarqand, by the order of (*bi-rasm*) Mawlānā Ḥasan Efendī, one-time Rūznāmijī of Cairo, al-Khalwatī al-Damurdāshī, by (*ᶜalà yad*) the weakest of the servants and most in need of God's mercy on the day of resurrection, humble in his deficiencies and shortcomings, Riḍwān, the unworthy. That was at the time of the first day of the 4803th year of the Era of the Flood (*ṭūfānīyah*)—that is, the day the great light [sun] passed into the House of Aries—being Monday the eleventh day of the month of Shawwāl in the year 1112 H, and that is the fourteenth of Barahāt [seventh month] of the 1417th Coptic (*qubṭīyah*) year, and the tenth of Adār of the year 2012 of the Greek Alexandrian era, and the twentieth of Tirmāh of the year 1070 of the Yazdijird era, and the first day of Farwardīn [first month] of the year 623 of the Malikshāh era. The completion of the remainder of the globe, with the help of God, may He be exalted!, was in the month of Ṣafar al-Khayr of the year 1113 H. God is sufficient for us; an excellent Guardian is He.

The globe rests in the probably original three-legged, S-curve, metal stand 324 mm in height with a central pedestal stand supporting the meridian ring. The meridian ring is graduated by single degrees with every fifth indicated by a longer line and labeled in *abjad* numerals in non-consecutive segments of 90° beginning at the poles and terminating at the points opposite the celestial equator. The horizon ring has four concentric circles. The inner circle is graduated by single degrees with every fifth indicated by two longer lines and every tenth by an even longer line. The single line indicating the 10° intervals extends to the outermost edge of the horizon ring, through all four concentric circles, while the double line indicating the 5° division passes through the two innermost circles. The second concentric circle has the names of the four cardinal points and labels each 5° interval with *abjad* letters in non-consecutive segments of 90° beginning at the east-west points and ending at the north-south points where there are the notches for the meridian ring. The third circle bears the names of the 12 zodiacal signs allowing 30° for each sign. Reading counterclockwise from east there are Aries, Taurus, Gemini, (N) Cancer, Leo, Virgo, (W) Libra, Scorpio, Sagittarius, (S) Capricorn, Aquarius, Pisces. The outermost circle bears the names of 104 localities allowing two or three names per 10° interval. Reading clockwise from the east point they are: Ceylon (Sirnadīb), Santarah, the Silver Island, Sindūn (the two Sinds), the Indian Island, the Black Sea, al-Baḥrayn, (island of) Socotra, Ṣaᶜadah, Qalhāt, Sharjah, Benī Hilāl, Haḍrmawt, Maqdūshah, al-Zinj, Sofalah (lit. Suqālah), Marmarah, Ṣanaᶜā, Bihāmah, ᶜArafāt, al-Ṭāʾifah, [S], Aden, Zabīd (in S. Arabia), Bilād al-Zaʾilaᶜ, Benī Shaᶜbah, the city of Qus, ᶜAshwah [?], the Yemen, Mārā, Sabā, Ẓafār, ᶜIraq, Jabal al-Qamar (Mountain of the

Moon, Mount Kilimanjaro), Bilād al-Sūdān (the Sudan), Mahrah, Khāsah, al-Mihrjān, Maẓhar al-Nīl, Tikrūr, Bilād al-Barbar (land of the Berbers), Kūkū, ᶜĀdiyān [?], Danqalah, Zaghāw, Jiddah, Ḥabashah (Abyssinia), al-Quṣayr, [W], Marākash, Fas (Fes), Tilimsān (Telemsan), Tuwān, Tūnis, Qayruwān (Kairouan in Tunisia), Ṭarāblus al-Gharīb (Tripoli in North Africa), Barqah, Aujlah, Asyūṭ, Fayyūm, Rashīd (Rosette), Damiyāṭ (Damiette), Miṣr (Cairo-Fuṣṭāt), Maḥallah, Istānapūl (Istanbul), Adrinah (Adrianopel), ᶜAqabah, Muwayliḥ, Tūr (Sinai), Baᶜalbek, Ṣaydā, Damashq al-Shām (Damascus), Ḥamā, Ḥamṣ, Wajah, Ḥalab (Aleppo), Malaṭiyah, Badr, Shaṭṭ (Tigris), Rābigh, Masājid ᶜĀʾishat al-Madīnah al-Munūrah (the mosques of Medina?), [N], al-Mawṣil, Bābāl (Babel), Shiwān, Hīt, Baghdād, Kūfa, al-Qādisiyah, Qazwīn, Bulghār, Khurāsān, ᶜAbādān (S. of Baṣra), Baṣra, Nisābūr, Kāzirūn, Balkh, Bukhārā, Samarqand, Sābūr, Iṣfahān, Sadd Yājūj (wall or mountain of Yajuj), al-Hind (India), Kābul, Hurmūz, and Hurmuz.

Formerly in the collection of Clot Bey; given to library in 1859.

Entry based on published accounts.

Citations

Dorn [1865], 31–44; a thorough description of globe and inscriptions and star names; no reproduction of constellation outlines.
Stevenson, 1:32.
Mayer [1956], 81–82.
Muris & Saarmann, 38.
Tchenakal, 293.
Czenakal, 57 and photograph figure 3.

32.

Location: Oxford. Museum of the History of Science, Billmeir Collection; Inventory No. 57-84/26.
Dated: [1]121 [H] [AD 1709–1710].
Maker: Unsigned.

Metal; no seam observable nor felt with probe inside; no plugs observed; no visual inspection of inside was possible; some sand and pebbles inside, possibly remaining from casting; dark finish. Diameter 150 mm. Full set of constellation figures with more that 1018 stars indicated by inlaid silver points surrounded by engraved circles. Ecliptic latitude circles. Equator and ecliptic graduated by intervals equivalent to 5° with each labeled; ecliptic repeats every 30° and equator is numbered continuously from vernal equinox. Zodiacal names are *not* engraved along ecliptic. Constellations and some stars labeled; *naskhī*. Stars are arranged in a decorative manner and are so poorly positioned on globe that it is impossible to determine epoch for which it was intended. The lines representing the ecliptic and equator are wobbly and the constellation figures poorly drawn and placed. A technically non-functional and inaccurate globe, probably Indo-Persian in origin.

A decorative quadruped metal stand on a ring base supports a horizon ring graduated by two degrees with every sixth labeled in non-consecutive segments of 90° converging at the notches for the meridian ring. The legs of the stand have at the tops and bottoms an elongated spiral design while the middle sections are engraved with human figures and floral motifs; the ring base has a braided design. To the underside of the horizon ring beneath the zero points is a semicircular band for supporting the meridian ring and globe. This band bears a two-part inscription in Persian reading, "By order of (*bar ḥasb*; or *bar khabīr*, for the knowledgeable) the learned, honorable, gracious master, the prince Muẓaffar ᶜUbayd al-Raḥīm, the completion occurred in the year [1]121." This is by no means a definitive translation. Many of the words are difficult to make out with certainty and can be read in several ways.

The meridian ring is graduated on both sides by 2° intervals with every sixth degree labeled in non-consecutive segments of 90° beginning at the points of attachment to the globe; its outside edge is inlaid with a row of silver points. The stand and rings are contemporary with the globe.

Compare this globe with globes Nos. 45 and 46, which display similarities of design and execution.

Formerly in collection of M. Henri Michel.

Citations

Michel [1938], photograph in plate VI and on cover.
Josten, 20, no. 26.

33.

Location: Present location unknown.
Date: AD 1842, 1258 H, and 1899 Vikrama Era.
Maker: Lālah Balhūmal Lāhūrī.

Metal; no seam observable; one large plug near south poles and several smaller plugs observable. Diameter 330 mm. Full set of constellation figures with about 1018 stars indicated by inlaid silver points. Ecliptic latitude circles; six meridian circles intersecting equator at 24°, 54°, 84°, 114°, 144°, 174°, 204°, 234°, 264°, 294°, 324°, 254° (there is no meridian circle representing the equinoctial colure); equatorial tropics; two lesser circles at 12° and 20° from equator on both sides of equator; equatorial polar circles. Ecliptic and equator graduated by single degrees with every sixth degree indicated by longer line, and labeled; ecliptic repeats every 30°; equator labeled each 6° segment with one numeral (1, 2, 3, 4, . . . 60) numbering continuously from vernal equinox. Zodiacal names engraved along ecliptic; constellations labeled and numbered; major stars labeled and all stars numbered within a constellation; *naskhī*, tending toward *taᶜlīq*. There are traces evident of a very light marking of the great circles which were then incised more deeply over the first markings; particularly evident at the crossings. Graduations and circles precisely executed. Near south equatorial polar circle is a lengthy inscription in Persian with small floral decorations interspersed among the eight lines:

The celestial globe encompasses the visible nature of the sphere of the ecliptic and 10 great circles, among which are the horizon circle [ring], meridian circle [ring], zenith ring (*dāʾirat sumūt*) and altitude ring (*dāʾirat irtifāᶜ*)—each of these four surrounding the globe itself—and the celestial equator, ecliptic, ecliptic latitude circles (*dawāʾir ᶜurūḍ*), solstitial colure (*marah bi-aqtāb arbaᶜah*), lacking [the circle of] inclination*, and declination circles (*dawāʾir muyūl*, meridians); these six circles move with the body of the globe, drawn and designed over 48 constellations—i.e., 21 north, 15 south, and 12 constellations which are along the main part of the zodiac which exists in the middle—and 1022 observable stars which are indicated by silver nails, resulting in a summary of the principles relating to time, place and direction, which are called the Three Principles. By order of the exalted benefactor and wealthy (*gunjūr*) Singh Ṣāḥib, benefactor of [his] time, unique in [his] lifetime, the end of [his] epoch, Nihāl Singh Ṣāḥib Bahādur Ahluwālīyah,† who in all sciences, especially the science of mathematics—which is to say astronomy and geometry—is incomparable and unique in the world, through the efforts of Lālah Balhūmal Lāhūrī, astronomer, geometer, and astrologer, who is one of those attending the honorable Singh Ṣāḥib mentioned before, and who was paid a bonus of 10 *ashrafī*‡ [in addition to] 480 *ashrafī* on completion of the design, an object of special favours, it was made in 1899 in the Vikrama Era§ corresponding to 1258 H, which is equal to AD 1842. It was placed at the capital Kapūrthalah.

A three-legged metal stand supports the horizon ring having attached to the underside a semicircular arc which holds the nadir of the meridian ring. The S-curve legs on feet are attached to the horizon ring by winged bolts. Over the top of the globe, at right angles to the meridian and horizon rings, is a semicircular arc attached to the horizon ring, corresponding to the prime vertical and indicating the zenith; the outer edges and two sides are decorated with an engraved floral motif, as are also the three legs. The outside edge of the horizon ring is engraved with an acanthus leaf pattern. The horizon ring is graduated by single degrees with every sixth marked by a longer line and labeled in non-consecutive segments of 90° beginning at the decorated upper semicircular arc (zenith ring) and ending at the notches holding the meridian ring. The meridian ring is attached to the equatorial poles of the globe by two screws. One half of the meridian ring is nearly flush against the surface of the globe, while the other half (from pole to pole) is cut away so as to permit a small slide (6° in width) attached to it to move along the 180° arc, no doubt for recording and comparing coordinates. The slide itself is graduated on its edge by single degrees. The half of the meridian ring with the slide is graduated by single degrees and the other half by single degrees with every sixth indicated by a longer line. The outside edge of the meridian ring is graduated into 6° intervals with each labeled 6, 12, . . . in non-consecutive segments of 90° beginning at the poles and converging at the points alongside the celestial equator. The stand and rings are probably contemporary with the globe. The design of the stand, rings, and globe itself are remarkably similar to the one known

globe entirely in Sanskrit (No. 54) which is unsigned and undated. The globe is also strikingly similar to the anonymous globe No. 90 (see No. 127 in the Addendum to this catalog, for another globe made in the same year by Lālah Balhūmal).

See Figure 24 for an illustration.

Formerly in the collection of the Maharajah of Kapūrthalah; offered for sale in Geneva in 1976.

Entry based on photographs in the files of the Whipple Museum of the History of Science, the Museum of the History of Science at the University of Oxford, and the files of A. Brieux and F.R. Maddison.

Citations

Galerie Genevoise horologerie ancienne, 9 rue de la Corraterie, Vente aux enchèves, III, Expert: O. Patrizzi, 3 October 1976 (sale catalog). Item no. 229, where it is incorrectly stated to be made in 1048 H [AD 1628]; photograph, plate 36.

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* It reads simply ᶜadīm al-mayl (lacking inclination); the meaning is obscure. Perhaps the maker intends to say that the globe is lacking the equinoctial colure, which is called *dāʾirat al-mayl*, thus reading it *ᶜadīm dāʾirat al-mayl*.

† Ahluwālīyah is clearly intended, although the engraver has mistakenly written al-Huwālīyah.

‡ The text speaks of *guldār ashrafī*; *ashrafī* are gold coins, and *guldār* meaning "decorated with flowers" must refer to a coin of a particular floriate design.

§ An era by tradition founded in 58 BC by King Vikramāditya of Ujjaim to commemorate a victory, but thought by many to have been founded by Azes I. The era is still current in India today.

Anonymous and Undated

34.

Location: Paris. Bibliothèque Nationale, Département des Cartes et Plans; Inventory No. Ge. A. 325.
Estimated Date: AD 1080 (not inscribed).
Maker: No signature.

Metal; hemispheres joined at equator. Diameter 190 mm. Full set of constellation figures with 1004 stars indicated by engraved circles having a dot in the center. Ecliptic latitude circles; small circles mark ecliptic poles. Ecliptic and equator graduated by single degrees with every fifth labeled; ecliptic repeats every 30°, equator is labeled continuously from vernal equinox. Zodiacal names engraved along ecliptic; equatorial poles, constellations, and major stars labeled; Maghribī Kūfic.

The style of the nude, rubbery figures so closely resembles the globe No. 1 by Ibrāhīm ibn Saᶜīd al-Sahlī made in Spain in AD 1080, that it might well be attributed to the same maker. The difference in longitude of the stars corresponds, according to Destombes, to the year AD 1067, slightly earlier than globe No. 1.

It has a curved quadruped stand meeting to form a pedestal support for the two semicircular arcs holding the horizon ring. Horizon ring graduated by single degrees with every fifth labeled in Kūfic script; numbering of graduations is in non-consecutive segments of 90° converging at notches for meridian ring. No meridian ring.

Acquired in 1936; formerly in collection of D. Schiepati of Milan.

Citations

Schiepati. Asserts it was made in 463 H/AD 1070.
Sédillot [1841], 115–141. Lists all the constellations and numbers of stars in each; asserts it is of thirteenth-century Egyptian origin.
Jomard, no. 13 and no. 14; includes two plates of lithographs.
Vallée, 48, no. 304.
Stevenson, 1:31.
Fiorini, 37.
Destombes [1957], 318, no. 1.
Destombes [1958] 305–306.
Muris & Saarman, 36.

35.

Location: Paris. Private collection of Marcel Destombes.
Estimated Date: AD 1309–1315 (not inscribed).
Maker: Unsigned.

Metal; very clear seam along ecliptic with lip of lower hemisphere over which upper hemisphere fits. Dark-colored surface, slightly dented. Diameter 209 mm. Full set of constellation figures with 930 stars indicated by silver inlaid points, each star numbered within the constellation. Square holes at both ecliptic and equatorial poles. Ecliptic latitude circles. Ecliptic and equator graduated by single degrees, with every fifth indicated by a longer line and labeled; the equator beginning at the vernal equinox has three

segments of 100° and one of 60° while ecliptic repeats every 30°. Zodiacal names engraved along ecliptic; celestial poles, constellations and 145 stars labeled; Kūfic.

The iconography of the figures suggests Ilkhānid design, and the style is analogous to that of globe No. 5. After studying the differences in longitude of 800 stars, Destombes concludes that this globe is quite close in date to No. 5, suggesting a date of about five years later, (AD 1309–1315), and a place of origin of Marāgha, Sultanye, or Tabrīz. This globe, as well as the other globes produced before 1500, will be analyzed in detail in a forthcoming publication by Marcel Destombes.

Modern pedestal stand. No rings.

Acquired in 1953. Formerly in Chadenat Collection, no. 6804.

Citations

Destombes [1957], 320, no. 7.
Destombes [1958], 307, note 2.
Muris & Saarmann, 37–38.

36.

Location: London (Greenwich). National Maritime Museum, Department of Navigation; Inventory No. G.141. 36.302.
Date: Not inscribed.
Maker: Unsigned.

Painted wood, gilt ground with black, white and red oil paint; lacquered. Diameter 165 mm. Full set of constellation figures outlined in black; animals are filled in with red dots, while human figures wear striped clothing. About 1018 stars indicated by indentations filled in with white paint. Ecliptic latitude circles; ecliptic polar circles; equatorial polar and tropic circles in red. Ecliptic and equator are indicated by two close parallel red circles and are graduated by single degrees, each indicated by a dot, with every third degree indicated by a line. Between the equator and each tropic there are two additional red parallel, labeled circles: the tropic (*madār*) of Gemini and Leo and the tropic of Taurus and Virgo about 4° and 12°, respectively, from the Tropic of Cancer, while at 4° from the Tropic of Capricorn is a tropic of Aquarius and Sagittarius and about 12° away is the tropic of Scorpio and Pisces. Zodiacal names written along ecliptic; major stars are labeled in black; *naskhī*. Stars seem well placed and their positions relative to the equinoxes conform to those of the early seventeenth century. The representation of the constellation figures differs considerably from those on other known globes. Iconography as well as calligraphy suggests the eastern borders of Persia, possibly Bukhāra in Afghanistan or across the Oxus in Samarqand as a point of origin.

The metal pedestal stand supporting two semicircular arcs to which the horizon ring is attached is recent. The horizon ring is graduated by two degrees with every tenth labeled in nonconsecutive segments of 90°, converging at the two notches which hold the meridian ring. Meridian ring ungraduated.

See Figure 19 for an illustration.

Exhibited at the exhibition "Science and Technology in Islam" held at the Science Museum, London, as part of the Festival of the World of Islam, April–August 1976.

Citation

Maddison & Turner, 84.

37.

Location: Bombay. Cama Oriental Institute, 136B Samacher Margl., Bombay, Fort.
Date: Not given.
Maker: Unsigned, but bears patron's name.

Metal; seamless with large plug near south poles which interferes slightly with the inscription giving patron. Diameter 203 mm. Full set of constellation figures; stars indicated by inlaid silver points. Ecliptic latitude circles; equatorial polar circles. Equator and ecliptic graduated at 2° intervals. Zodiacal houses engraved along ecliptic; constellations, major stars, and equatorial poles labeled; *naskhī* tending toward *ta^clīq*. Dress of the human constellation figures does not appear to be Mughal but rather reflects other Indian influences. The name of the patron for whom the globe was executed is given in an inscription which reads: "The one [who is] in need of God, Abū al-Qāsim, son of our master

and teacher, the paragon of his age and unique in his time ᶜAbd al-Raḥmān ibn Ḥasan, requested it be made and figured for him. May God bestow much mercy on them both."

Thus one Abū al-Qāsim ibn ᶜAbd al-Raḥmān ibn Ḥasan requested that the globe be executed. Nothing is known of either the son nor the learned father.

The globe is supported by a stand, details unknown.

No further information available; no photograph published. Information on inscription and general appearance furnished by Dr. Ismail K. Poonawala of the Department of Near Eastern Languages, UCLA, who was kind enough to inspect the globe for me.

Citations

Rehatsek, 329. Gives the inscription.
Mayer [1956], 33. Gives the name Abū al-Qāsim ibn ᶜAbd al-Raḥmān ibn Ḥasan as the maker rather than the patron.

38.

Location: Washington, D.C. Smithsonian Institution, National Museum of American History, Division of Physical Sciences; Inventory No. NMAH 330,781.

Metal; seamless with many plugs observed; cast by *cire perdue.* Diameter 217 mm; weight 2976.7 grams. Full set of constellation figures; 1019 stars indicated in inlaid silver points. Ecliptic latitude circles. Appears incomplete; northern equatorial tropic circle not correctly placed and only partially engraved. Ecliptic and equator graduated by ½° intervals with every fifth full degree labeled; ecliptic labeled continuously from vernal equinox; equator numbered in two 180° segments. Zodiacal names engraved along ecliptic; names of the 28 lunar mansions also engraved along ecliptic on opposite side from zodiacal names and at marked intervals of approximately 13° Constellations and many stars labeled; *naskhī.*

Stand and rings missing.

See Figures 49–68 and 70–88 for illustrations.

Acquired by museum in 1974; formerly in collection of Ernst Nagel of San Francisco.

Citations

Previously unpublished; this globe is the focus of the present monograph.

39.

Location: Present location unknown.

Metal; no seam observable; several small plugs visible. Diameter 115 mm. Full set of constellation figures with about 1018 stars indicated by inlaid silver points. Ecliptic latitude circles. Ecliptic and equator graduated by 5° intervals (with no single degree graduation); ecliptic repeats numbering every 30°, while equator is numbered in four segments of 90° each. Zodiacal names engraved along ecliptic. Constellations and major stars labeled; *naskhī.* This is definitely a product of the seventeenth-century Lahore workshop. Star positions relative to equinoxes are same as those of Lahore workshop. The globe closely resembles globe No. 23 made by Ḍiyāᵓ al-Dīn Muḥammad in 1068 H/AD 1657–1658, although there are certain characteristics, such as the depiction of Argo and the dress of Auriga, which are reminiscent of the work of the father Qāᵓim Muḥammad as seen on globes No. 11 and 13.

Ungraduated meridian ring. Later base not illustrated in published photograph.

Entry based on sales catalog when offered for sale in London by Spink & Son in 1980.

Citation

Islamic Art from India (sale catalog). Spink & Son. 24 April–10 May 1980. Item 5, with photograph.

40.

Location: Chicago, Illinois. Adler Planetarium and Astronomical Museum, Mensing Collection; Inventory No. M14.

Metal; no seam observable; several plugs visible including one large oblong one; rattles; clearly polished on lathe. Diameter 169 mm; weight 1835.7 grams. Full set of constellation figures with about 1018 stars indicated by inlaid silver points. Ecliptic latitude circles. Ecliptic and equator graduated by single degrees with every

fifth labeled; ecliptic repeats every 30°; equator is numbered continuously from the vernal equinox. Zodiacal names engraved along ecliptic; equatorial and ecliptic poles, constellations and many stars labeled; *naskhī*. Has several small dark engraved circular patches ringed by dark dots (one in Serpentarius and three in Leo) whose purpose is not known. Clearly two different engravers worked on globe, for Boötes, Hercules, and the Northern Crown are rather crudely drawn and lightly incised with some parts redrawn, while the other figures are well executed and deeply engraved. Star positions relative to the equinoxes conform to those of the seventeenth-century Lahore workshop. Iconography Mughal.

Quadruped metal stand on eight-lobed ring base resting on four spherical legs, with two cross bars holding a central support for a semicircular arc beneath the globe. This semicircular arc bears the names of 42 localities with their corresponding longitudes and latitudes; there are 23 on one side and 19 on the other, each side beginning with the words *asmāʾ bilād, ṭūl,* and *ʿurḍ* (names of cities, longitude, and latitude). The cities are: Mawṣil (Mosul), al-Zubayr, Marand, Nakhjawān (Nakhichevan in Azerbaijan), Marāgha, Tabrīz, Kūfah, Baghdād. Baṣra, ʿAbādān, Firūzābād (the earlier Gor in Persia, not the one in India), Shīrāz, Yezd, Shahrazūr, Nahāwand (Nehawend) Abhar, Hamadān, Narakh, Qazwīn (Kazvin), Iṣfahān, Qum, Rayy, Astarābād (Astrabad); Medina (Medinah Rasūl), Mecca (Meccah Muʿaẓẓamah), Hajar in Baḥrayn, Jerusalem (Bayt al-muqaddas), Mahdia, Qayruwān (Kairowan), Ṭarāblus Maghrib (Tripoli in North Africa), Andalus (Southern Spain), Alexandria, Miṣr (Cairo-Fusṭāt), Aden, Yemen, Zabīd, Asqalān (Ascalon), Tiberias, Ṭarāblus Shām (Tripoli in the Lebanon), Damascus, Baalbek, Ḥalab (Aleppo). The horizon ring is graduated by single degrees with every fifth labeled and bears the names of the four cardinal points and the four intermediate directions near outer edge of ring; numbering is in non-consecutive segments of 90° beginning at the north-south points, where there are also two notches for the meridian ring, and converging at the east-west points. The outside edge of horizon ring is divided into about 16 groupings of three segments each, one large and two smaller, separated by engraved double lines; in one grouping there is engraved *asmāʾ al-buldān* (the names of cities) in the large section, *ṭūl* (longitude), and *ʿurḍ* (latitude) in the two smaller sections; the other spaces are left blank, indicating that the ring and stand were never completed. On the underside of the horizon ring are also the words *asmāʾ bilād, ṭūl,* and *ʿurḍ* (names of cities, longitude, and latitude).

The meridian ring is graduated on one quadrant by single degrees with every fifth labeled beginning at a point marked North and proceeding clockwise. From the point labeled North, there are a series of holes anti-clockwise along the ring labeled 10°, 18°, 24°, 27°, 32°, 40°, 48°, 54°, 66° 30′, 72°, and 90°, the latter hole having a special dark inset and being labeled "up" (*fawq*). Continuing anticlockwise from "up" the next quadrant is ungraduated and contains no holes. Continuing with the remaining quadrant, the zero point is labeled South, and there are holes labeled 10°, 18°, 24°, 27°, 32°, 40°, 48°, 54°, 66° 30′, and 72°. Thus if the ring is positioned on the horizon ring with the North point on the north point of the horizon ring (and the South point on the south point) and the point marked "up" at the top to mark the zenith, the axis of the globe can then be set at 10 specified northern geographical altitudes; there is no accommodation for southern latitudes. A pin passes through the meridian ring and the equatorial (celestial) poles.

Citations

Engelmann, 12.
Guide to the Adler Planetarium, 25 (photograph).

41.

Location: Chicago, Illinois. Adler Planetarium and Astronomical Museum; Inventory No. A 140.

Metal; no seam observable; five plugs visible and one figure-eight hole where there was once a plug. Diameter 165 mm; weight 1942 grams; wall thickness 2 mm. Full set of constellation

figures with about 1018 stars indicated by inlaid silver points. Ecliptic latitude circles. Ecliptic and equator graduated by single degrees with every fifth labeled; ecliptic repeats every 30°; equator numbered continuously from vernal equinox. Zodiacal names engraved along ecliptic; constellations and major stars labeled; *naskhī*, engraving filled in white. Star positions relative to the equinoxes conform to those of the seventeenth-century Lahore workshop. While star placement, engraving of circles and graduations are precise, the constellation figures are rather crudely drawn. Surface of globe badly scratched and beaten. Probably Indo-Persian product of seventeenth-century Lahore.

Metal quadruped stand on ring, eight-lobed base with cross bar, but with no undersupport for globe. Stand and horizon ring clearly made to go with a different globe, for the ring is too small for this globe and does not allow globe to rest with ring at its mid-point. Horizon ring graduated by single degrees with every fifth labeled in non-consecutive segments of 90° converging at the two notches for the meridian ring which are labeled north and south; bears the names of the four cardinal points near outside edge of horizon ring. A 90° graduated arc (same pattern as ring) is attached and hinged to the top of the horizon ring to serve as a marker for zenith and prime vertical. Ungraduated (recent) meridian ring.

Citation

May be the globe referred to by Yonge, 83, as being at the Adler Planetarium; otherwise unpublished.

42.

Location: London (Greenwich). National Maritime Museum. Department of Navigation; Inventory No. G 175.36.378.

Metal; no seam observable; two plugs visible; rattles slightly; and two white pebbles inside, possibly remnants of casting process; weight is biased. Diameter 108 mm; weight 104.8 grams. Full set of constellation figures with about 1018 stars indicated by inlaid silver points. Ecliptic latitude circles. Ecliptic and equator graduated by single degrees with every sixth labeled; ecliptic repeats every 30°; equator numbered continuously from vernal equinox. Zodiacal names engraved along ecliptic; constellations and many stars labeled; *naskhī*. The 12 zodiacal figures and the solsitial colure are engraved with dotted lines. Star positions relative to the equinoxes conform to those of the seventeenth-century Lahore workshop. Iconography Mughal and similar to several of the globes by Ḍiyāʾ al-Dīn Muḥammad.

Metal quadruped stand on ring base with semicircular support for globe attached to underside of horizon ring. Horizon ring graduated by single degrees with every sixth labeled in non-consecutive segments of 90° beginning at the two notches for the meridian ring; bears the names of the four cardinal points near outside edge of ring. At the center of the semicircular undersupport in the notch to accommodate the meridian ring is a hole possibly threaded for a screw to hold firm the meridian ring. Meridian ring missing. Horizon ring and stand appear to be contemporary with globe.

43.

Location: Present location unknown.

Metal; no seam observable; one round plug visible. Diameter 180 mm; overall height with stand and meridian ring 285 mm. Full set of constellation figures and about 1018 stars indicated by inlaid silver points having a dot in the middle of each; some variation according to magnitude. Ecliptic latitude circles; equinoctial colure; equatorial tropic and polar circles; ecliptic polar circles. Ecliptic and equator graduated by single degrees with every sixth labeled; ecliptic repeats every 30°; equator labeled in four segments of 90° each. Zodiacal names engraved along ecliptic; tropics, ecliptic polar circles, constellations, and major stars labeled; *naskhī*. Star positions relative to the equinoxes conform with those of the seventeenth-century Lahore workshop. Iconography Mughal. Carefully executed engraving.

Modern stand consisting of four ebony spindle legs on round feet resting on two ebony cross-

bars with a brass plaque in the center. The legs support an ungraduated metal horizon ring inlaid with a ring of ebony. The metal semicircular support for the globe which is attached to the underside of the horizon ring terminates in an ebony finial. Ungraduated metal meridian ring. The design of the modern stand is of Mughal inspiration.

Entry based on photograph and description in sales catalog.

Sold in Paris in 1980. Formerly in collection of Leonard Linton of Point Lookout, New York.

Citations

Collection of Leonard Linton (sale catalog). Sale: Nouveau Drouot, 9 rue Drouot, 9–10 October 1980. Commissaires-Priseurs: E. Libert and A. Castor. Expert près les Douanes: A. Brieux. Item no. 224, p. 176; photograph p. 177.

44.

Location: Chicago. Adler Planetarium and Astronomical Museum; Inventory No. A 115.

Metal; no seam observable; three plugs visible including two large round plugs in line on opposite sides of the sphere; rattles slightly. Diameter 115 mm; weight 921.4 grams. Full set of constellation figures and about 1018 stars indicated by very small inlaid silver points. Ecliptic latitude circles; it appears that a circle with the south equatorial pole as center was begun but not finished; the circle would have been between the south tropic circle and the south polar circle had it been completed. For this reason work was probably stopped on globe and no holes were drilled at either the equatorial or ecliptic poles, and the signature of maker was not put on it (cf. No. 38). Ecliptic and equator graduated by single degrees with every fifth labeled; ecliptic repeats every 30°; equator is numbered continuously from the vernal equinox. Zodiacal names engraved along ecliptic; constellations and major stars labeled; *naskhī*. The 12 zodiacal constellation figures are engraved with dotted lines. No hole drilled at either the equatorial or ecliptic poles; however, two (?recent) large holes drilled opposite each other about 25° east of the equinoxes; purpose unknown. Star positions relative to the equinoxes conform to those of the seventeenth-century Lahore workshop. Iconography Mughal. Fairly carefully executed engraving.

Stand and rings missing.

On loan for exhibit to the Hayden Planetarium, New York, from 1964 through March 1974.

45.

Location: London (Greenwich). National Maritime Museum. Department of Navigation; Inventory No. G.7.36.383.

Metal; no seam observable and no seam felt inside; one large (?recent) plug in southern hemisphere; visual inspection of interior not possible. Diameter 115 mm; weight with meridian ring 550 grams. Full set of constellation figures with at least 1018 stars indicated in inlaid silver points. Ecliptic latitude circles. Ecliptic and equator graduated by 5° intervals (not single degrees) with every unit equivalent to 5° labeled; ecliptic repeats every 30° while equator is numbered continuously from the vernal equinox. Zodiacal names engraved along ecliptic; constellations and major stars labeled; *naskhī*. Zodiacal constellation figures engraved with dotted lines. Has two holes drilled opposite each other about 25° east of the equinoxes whose purpose is unknown (similar in this respect to No. 44). The ecliptic and equator are poorly drawn and somewhat wobbly. Star positions are very poor, with extra stars frequently being added in a somewhat decorative manner, filling in many areas both inside and outside the outlines which should otherwise be without stars. Position of the stars with regard to equinoxes is difficult to determine since stars so poorly placed; both Spica and Regulus (both labeled) are misplaced and far from the ecliptic. A technically non-functional and inaccurate globe. Iconographical design basically similar to preceding globe (No. 44) but crudely executed. Could possibly have been made by same maker as produced No. 32 and No. 46. Possibly an eighteenth to nineteenth-century Indo-Persian product.

A decorative quadruped metal stand on a ring base supports an horizon ring graduated by two

degrees with every sixth labeled in non-consecutive segments of 90° converging at the notches for the meridian ring. The legs of the stand are engraved with human figures and other decorations and have three knobs in the middle of each. A modern semicircular band attached to the horizon ring supports the globe and meridian ring. The meridian ring is graduated by two degrees with every sixth labeled in non-consecutive segments of 90° beginning at the two points at which the ring is attached to the globe. The ring base bears an undeciphered inscription, possibly nonsensical, engraved in bas relief on a black background, enclosed in a band. Horizon ring, stand, and meridian ring may be contemporary with globe, although their graduations do not match those of the globe.

46.

Location: Bloomfield Hills, Michigan. Cranbrook Institute of Science; Inventory No. T-88.

Metal; according to the Curator there is a seam in the plane halfway between that of the equator and that of the ecliptic, but this is not visible in the photographs. Diameter 150mm. Constellation outlines with stars indicated by engraved circles. Ecliptic latitude circles. Ecliptic and equator graduated by 5° intervals (not single degrees) each numbered, equator labeled continuously from vernal equinox; ecliptic repeats every 30°. Zodiacal names *not* engraved along ecliptic. Constellations and some stars labeled; *naskhī.* Constellation outlines crudely executed; stars very inaccurately placed and seem arbitrarily positioned so as to fill spaces symmetrically in and outside the constellation outlines. The iconography has some interesting features such as a bird in place of Delphinus and Equus. Position of the stars with regard to the equinoxes is impossible to determine since the stars are so poorly placed. A technically non-functional and inaccurate globe produced for artistic rather than scientific purposes.

Metal quadruped stand; the spindle legs each have a center knob and are covered with engraved floral patterns. The horizon ring is graduated by two degrees with every sixth labeled in non-consecutive segments of 90° converging at the notches for the meridian ring. The meridian ring is graduated by two degrees with every sixth labeled in non-consecutive segments of 90° beginning at the points of attachment to the globe. Graduations uneven and poorly executed. There appears to be no undersupport for the globe, and the meridian ring and globe do not fit properly into the horizon ring.

See Figure 23 for an illustration.

There is considerable similarity between this globe and stand and the globe and stand in No. 45, as well as some similarity with No. 32. Possibly an eighteenth or nineteenth century Indo-Persian product.

Bought in 1953 in Cairo and given to the museum.

Entry based on information and photographs supplied by the Cranbrook Institute of Science and a photograph in the files of the Museum of the History of Science, Oxford.

Citation

Yonge, 88.

47.

Location: Present location unknown

Metal; no seam observable; one large round plug visible. Diameter 147 mm. Full set of constellation figures with somewhat rubbery human figures, with about 1018 stars indicated by inlaid silver points. Ecliptic latitude circles. Ecliptic and equator indicated by simple lines with no graduations. Constellations are labeled, but no word for constellation is used; *naskhī.* Zodiacal names are *not* written along ecliptic. Positions of stars with relation to the equinoxes conform roughly to the late seventeenth century. Although there are no graduations on the globe, the stars and constellation outlines are basically well placed and the engraving of the circles is uniform. Iconography is Mughal.

Rings missing.

Exhibited in Paris at the *Cinquième Congrès de l'Union Astronomique* in 1935, and in 1936 at the

exposition of *Instruments et Outils d'Autrefois* at the Musée des Arts Decoratifs, where it was listed as no. 13 in the catalog. Formerly in the collection of C. Chadenat (no. 53) until 1956, when it was sold at a public sale in Paris.

Description based on the one published photograph and two photographs in the files of F.R. Maddison.

Citation

Chadenat, sale item no. 43; photo, plate IX.

48.

Location: London (Greenwich). National Maritime Museum. Department of Navigation; Inventory No. G.4.36. 360.

Metal; seamless; can see inside that there is no seam and that there are protruding stumps from the casting process. There is a hole 26 mm in diameter where a plug once was. Diameter 127 mm; weight with steel axis rod 735.3 grams; wall thickness 0.43 mm. Full set of constellations somewhat crudely drawn and lacking in detail, with about 1018 stars indicated by inlaid silver points varying in size approximately according to magnitude. Ecliptic latitude circles indicated by very faint circles, the solstitial colure being a dotted line. Ecliptic indicated by a simple ungraduated dotted line and the equator by an extremely faint simple solid line. Zodiacal names *not* engraved along ecliptic; constellations and some stars labeled; *naskhī* tending toward *taᶜlīq*. Very similar in design and execution to globe No. 47.

Ungraduated horizon ring on quadruped stand with central square knob on legs on ring base, with inverted semicircular support for meridian ring. Meridian ring ungraduated.

49.

Location: Glasgow. Private collection of Arthur Frank, housed at Charles Frank Ltd., 145 Queen Street.

Metal; not known if in hemispheres. Globe is said to be "engraved with the ecliptic and equator, with several of the constellations."

Exhibited at the Glasgow Art Gallery and Museum, April–June 1973.

No further information available. Entry based on catalog description.

Citation

Nuttall, 44; where attributed to ca. AD 1600.

50.

Location: Present location unknown.

Metal. Diameter 97 mm. Constellation figures are engraved. Ecliptic latitude circles; polar circles. Quadruped stand on circular base; legs engraved in scroll pattern, connected in center by ring of twisted fluting. Meridian and horizon rings graduated by 3°. Height of support 160 mm.

No further information; entry based on sale catalog.

Formerly in the collection of Ch. Chadenat until 1956, when it was sold at a public sale in Paris.

Citation

Chadenat, sale item no. 51; date estimated as ca. AD 1790–1795.

51.

Location: Present location unknown.

Metal. Diameter 140 mm. Constellation figures engraved; some star names. Stand composed of horizon ring supported by four small baluster columns engraved with frondescent pattern, standing on a circular base.

In the collection of C. Chadenat unil 1956, when it was sold at a public sale in Paris. Entry based on sale catalog; no further information available.

Citation

Chadenat, sale item no. 53; attributed to AD 1795.

52.

Location: Present location unknown.

Metal; not known if in hemispheres. "Surface engraved with the ecliptic and equator and with

several of the constellations." Metal stand of three curved legs and horizon ring graduated by single degrees; height 270 mm.

This globe was sold by Sotheby & Co., London, in 1968; entry from sale catalog; no further information available.

Citation

Sale catalog of Sotheby & Co., London, dated Monday, 22 July 1968.

53.

Location: Present location unknown.

Metal; not known if in hemispheres or not; no seam or plug observable in photograph. Diameter estimated to be between 450 mm and 600 mm. Full set of constellation figures with about 1018 stars indicated by small inlaid silver points. Ecliptic latitude circles; six meridian circles intersecting equator at what would be (if equator had been numbered continuously) 24°, 54°, 84°, 114°, 144° ... 354°—that is, a 6° shift, with no meridian circle representing the equinoctial colure. Equatorial tropic circles; two lesser circles each 12° from equator and two lesser circles each 20° from equator. Silver points at ecliptic poles and at crossing of ecliptic and equator. Equator graduated by single degrees with each 6° segment assigned one number (1, 2, 3, 4, ... 60) numbering in both *abjad* and standard numerals continuously from vernal equinox. Each single degree segment contains three dots arranged in a triangle. Ecliptic graduated by ½° with every 5° segment numbered with an *abjad* as well as standard numeral, repeating every 30°. Zodiacal names deeply incised and blackened along ecliptic; the 48 constellations are labeled and numbered; *naskhī* tending toward *taᶜlīq*. No stars appear to be labeled, although they are numbered within each constellation.

Stars appear to have been placed after constellation outlines engraved; autumnal equinox not well drawn, with uneven number of degrees on either side. Stars rather inaccurately positioned, although corresponding for the most part to that of the middle nineteenth century. Although the star positions and general design correspond roughly to the globe made by Lālah Balhūmal Lāhūrī (No. 33), the iconography of the constellations and the engraving and possibly metallurgical techniques differ substantially from those of Balhūmal; furthermore the globe does not display the precision and accuracy of the Lālah Balhūmal globe.

A three-legged metal stand supports the horizon ring with a semicircular arc (attached by two winged bolts on each side) holding the nadir of the meridian ring. The slender S-curved legs on rounded feet are attached to the horizon ring by means of a winged bolt. Over the top of the globe, at right angles to the meridian ring, is a semicircular arc attached to the horizon ring; the two sides of this zenith ring are decorated with an engraved plant motif, with the outer edge having a figure of a European (?) soldier carrying a bayonet and also a floral decoration. On the triangular projection at the top of the semicircular arc marking the zenith there appears to be another engraved human figure in Indian dress. The outside edge of the horizon ring is engraved with an abstract pattern of arcs or peacock feathers. The horizon ring has on its top surface a floral design near the edge with an inner circle of numerals and writing not decipherable from the available photographs. The meridian ring has the two holes that should contain the axis of the globe labeled as north and south poles; three parallel circles are engraved around the outside edge of the meridian ring. One face of the ring is graduated by single degrees with every sixth labeled in *abjad* as well as standard numerals, beginning at the poles in non-consecutive segments of 90° converging at the points opposite the celestial equator (if mounted properly). The axis is missing so that the globe is not actually attached to the meridian ring. Stand and rings contemporary with globe.

Possibly middle nineteenth century or later Indo-Persian product.

Formerly in the collection of Hew Kennedy of Shropshire. Said to have been bought in Kapūrthalah along with a large astrolabe by Lālah Balhūmal Lāhūrī.

Entry based on photographs in the files of F.R. Maddison and A. Brieux.

54.

Location: New York City. Columbia University, Butler Library, David Eugene Smith Collection; Inventory No. 27-244.

A Sanskrit globe. Metal; no seam observable; two large plugs and several small ones visible. Diameter 205 mm. Full set of constellation figures with about 1018 stars indicated by inlaid silver points, now blackened. Engraving has been whitened. Ecliptic latitude circles; six meridian circles intersect the celestial equator at points (if the equator had been numbered continuously) 24°, 54°, 84°, 114°, 144°, 174°, 204°, 234°, 264°, 294°, 324°, and 354° (that is, there is no meridian circle representing the equinoctial colure, for the set of six circles has been shifted 6° westward); equatorial tropic circles; two lesser circles each 20° from equator; two lesser circles each 12° from equator; equatorial polar circles. Ecliptic and equator graduated by single degrees with every sixth indicated by longer line and labeled; ecliptic repeats every 30°; equator has the 6° segments of each 30° interval between meridians labeled 1, 2, 3, 4, 5. Sanskrit zodiacal names engraved along ecliptic; constellations labeled and numbered; stars numbered. Writing and numerals in Sanskrit, Devanāgarī characters. Stars are carefully positioned, corresponding to middle of nineteenth century, and graduations and circles precisely executed.

The three-legged metal stand supports an horizon ring with attached semicircular arc which supports the nadir of the meridian ring. The legs, in S-curve leaf design, resting on small decorated feet, are attached to the horizon ring by means of winged bolts. The outside edge of the horizon ring is engraved in an abstract pattern based on leaf and flower motifs. The horizon ring is graduated by single degrees with every sixth indicated by a longer line and labeled in non-consecutive segments of 90° beginning at the two notches which would hold the zenith ring (the semicircular arc corresponding to the prime vertical; now missing) and converging at the notches holding the meridian ring. The meridian ring is attached to the equatorial poles of the globe by screws and is constructed so that one half (from pole to pole) is nearly flush while the other is cut away from the surface of the globe so as to permit a small slide of 6° width to slide along it. The slide is graduated by single degrees. The outside edge of the meridian ring is divided into 6° intervals, each labeled 6, 12 . . . in non-consecutive segments of 90° beginning at the poles and ending at the points opposite the celestial equator. The edges near the globe are graduated by single degrees. Stand and rings probably contemporary with globe (zenith ring missing).

See Figure 25 for an illustration.

Indo-Persian product of the middle of the nineteenth century. The design of both the globe and stand and rings, including the iconography and star positions, are strikingly similar to that of globe No. 33 by Lālah Balhūmal Lāhūrī, and it is likely that the globe was produced by the same maker or by someone trained in his workshop.

Citations

Yonge, 83; where it is dated AD 1640.

Stevenson, 1: fig. *a* (opposite p. 17), reproduces a photograph of it incorrectly labeled "Anonymous Arabic Globe, 1635."

55.

Location: New Delhi, India. Red Fort Archaeological Museum.

Metal; no seam or plugs observable in available photograph. Diameter 150 mm. Full (?) set of constellation figures, but *no* stars. Ecliptic latitude circles. Ecliptic and equator graduated by single degrees with every fifth indicated by longer line and labeled; ecliptic repeats every 30° while equator is numbered continuously from vernal equinox. Zodiacal names engraved along ecliptic; *naskhī.* The graduations and circles appear to be precisely and uniformly executed. With no stars it is difficult to estimate the epoch, but the general positions of the constellation outlines corresponds to the late seventeenth century. This may be an unfinished globe.

Quadruped stand 121 mm in height, with six-sided tapered legs on rounded feet resting on an eight-lobed ring base with center cross-bars.

Semicircular support for globe is attached to underside of horizon ring. Meridian ring appears to be ungraduated; not known if horizon ring is graduated.

Probably Indo-Persian in origin. Entry based on short published description and a photograph in the archives of G.R. Kaye preserved at the Museum of the History of Science, Oxford.

Citation

Stone, 160.

56.

Location: London (Greenwich). National Maritime Museum, Department of Navigation; Inventory No. G180. A65-37.

Lacquered *papier mâché* on hollow wooden core. Diameter 152 mm. Black ground with white circles except for red equator; figures painted in white, browns and red; red labeling. There are approximately 48 constellation figures painted on this globe, but they are not actually constellation outlines, for no stars are depicted in them. In fact, there are no stars on this globe. Ecliptic latitude circles; equatorial tropics; equatorial and ecliptic polar circles; equinoctial colure. Ecliptic indicated by a simple, ungraduated white circle, and equator by a simple red circle. Zodiacal names are *not* written along ecliptic; only the constellation figures are labeled (no word for constellation); *naskhī.* Large holes at the ecliptic poles and only very small holes at the celestial equatorial poles.

The iconography is radically different from that usually found on celestial globes. For example, Gemini and Taurus are facing in the opposite directions from usual, Perseus has the sword and head in reversed hands and has his head toward the East. There are actually two Cassiopeias (*dhāt al-kursī* or "lady with the chair"); one roughly above Perseus where it ought to be, and the other along the equator north of Aquarius. Since there are no stars on the globe it is impossible to approximate the intended epoch or the time of construction, particularly since even the constellation forms are irregularly positioned. It is not unreasonable that this is a late eighteenth- or early nineteenth-century, possibly Persian, product. A technically non-functional and inaccurate globe representing a separate tradition in celestial globe design.

Stand and rings missing.

See Figure 29 for an illustration.

Acquired in 1965 from Sotheby & Co., London.

Citation

Weil, sale item no. 183; illustrated on the cover. This catalog is undated, but was issued between 1955 and 1965.

57.

Location: Paris. Private collection.

Metal; seam along equator. Diameter 200 mm. Stars indicated by inlaid points, some of which protrude from the surface of the globe. Full (?) set of constellation figures. Ecliptic latitude circles; equatorial tropic circles; circles about 12° and 20° from equator in northern hemisphere only. Equator and ecliptic graduated by two degrees with every tenth indicated by a longer line and labeled; ecliptic repeats every 30°, equator numbered continuously from vernal equinox. Zodiacal names engraved along ecliptic; constellations, equator, and *mayl kullī* labeled; *naskhī.* The constellation figures do not seem, from the one published photograph, to cover the required areas and represent a different iconographical tradition from the usual constellation diagrams. There are some stars, but only a few, within the outlines of the constellation figures. There appear to be many fewer stars than are common on Class A globes. The graduations are even and precise and the circles well executed, but the star positions are so irregularly spaced that the epoch to which they were intended to conform cannot be determined, at least from the one available photograph.

Metal pedestal stand on a circular decorative base with a semicircular arc attached to underside of horizon ring to support nadir of globe. Both rings graduated by single degrees with ev-

ery fifth indicated by a longer line.

Entry based on the one published photograph; no further information available.

Citation

Guye & Michel, 210, plate 199.

58.

Location: La Chaux-de-Fonds, Switzerland. Musée d'horologerie.

Metal; no seam observed; no plugs observed. Diameter not recorded. Globe has no stars. Does not have the usual constellation figures, but merely ornamental figures which appear to fill up the areas of the globe other than the area where the zodiacal names are engraved near the ecliptic in very large, double-outlined writing. Ecliptic latitude circles; ecliptic tropic circles; equatorial polar circles; equinoctial colure. Ecliptic and equator graduated by single degrees with every fifth labeled. Circles are rather poorly drawn on the globe and graduations are uneven. A non-functional and inaccurate globe.

Metal quadruped stand on a ring base with ornamental engraving on the legs. Horizon ring appears to be graduated by two degrees with every sixth labeled; meridian ring is ungraduated with ornamental engraving.

Entry based on photograph taken in May of 1972 by Uta C. Merzbach of the Smithsonian Institution.

Class B—Celestial Globes without Constellations

Signed or Dated

59.

Location: Tehran. Muzeh-i Iran-i Bastān.
Date: 535 H [AD 1140–1141].
Maker: Badr ibn ᶜAbdallāh Mawlā Badīᶜ al-Zamān.

Metal; in hemispheres with seam along ecliptic; probably cast hemispheres. Diameter 140 mm; height on stand 160 mm. No constellation figures; about 50 stars or star groups indicated by inlaid silver points or groups of silver points. Ecliptic latitude circles. Ecliptic and equator graduated by single degrees with every fifth labeled; ecliptic repeats every 30°; equator labeled in three segments of 100° each and one segment of 60° starting at vernal equinox. Zodiacal names engraved along ecliptic; stars labeled; lunar mansions written along ecliptic; Kūfic. Kūfic inscription north of the Houses of Gemini and Cancer reads: "The work of (*ṣanᶜat*) Badr ibn ᶜAbdallāh Mawlā Badīᶜ al-Zamān, year 535." A much later inscription in *naskhī* script has been added in the southern hemisphere on the other side of the equator from the previous one; it is dated 1304 H [AD 1886–1887] and records that the globe belonged to (*min mumtalakāt*) ᶜImād al-Dawlah ibn ᶜImād al-Dawlah ibn Muḥammad ᶜAlī ibn . . . ḥ ᶜAlī Shāh.

A meridian ring (not contemporary with globe), plain and ungraduated, is attached to the ecliptic poles. The meridian ring sits in a metal stand consisting of a horizon ring supported by four legs resting on a circular ring base. The horizon ring is graduated by single degrees with every fifth labeled in Kūfic *abjad* numerals in non-consecutive segments of 90° beginning at the notches holding the meridian ring. A non-functional hole has been drilled into the globe between the ecliptic and equator at the House of Cancer, possibly to see if anything was inside.

Entry based on information and photographs in the files of F.R. Maddison.

Displayed at the exhibition "Science and Technology in Islam" held at the Science Museum, London, as part of the Festival of the World of Islam, April–August, 1976.

Citation

Maddison & Turner, 76.

60.

Location: Oxford. Museum of the History of Science, Billmeir Collection; Inventory No. 57-84/181.
Date: 718 [H] [AD 1318–1319].
Maker: ᶜAbd al-Raḥmān ibn Burhān al-Mawṣilī.

Metal; no seam observable; 2 plugs visible; no seam detected by probing the rough interior

surface or with limited visual inspection of interior. Diameter 153 mm; weight 1488.3 grams. No constellation figures; about 100 stars indicated by inlaid silver points. Ecliptic latitude circles; equatorial and ecliptic polar circles. Ecliptic and equator graduated by single degrees with every fifth labeled; both equator and ecliptic repeat every 30°. Zodiacal names engraved along ecliptic in narrow double-outlined writing; names of the 28 lunar mansions also engraved near ecliptic; equatorial poles, equatorial polar circles, and most stars and star groups labeled; *naskhī*. The inscription near the north ecliptic polar circle reads: "The work of (*ᶜamal*) ᶜAbd al-Raḥmān ibn Burhān al-Mawṣilī in the months of the year seven hundred and eighteen."

Near the south poles are two inscriptions lacking many diacritical points and written rather poorly; they may possibly be by a different hand. The sense of the first seems to be: "Undertaken at the instigation of the poor, the weak (*al-faqīr al-ḥaqīr*) Ghiyāth known as al-Manṣūr in the months of the year .... (lacuna) and seven hundred." (The expression for "at the instigation of" is the mixed Arabic and Persian *maṭwà bar naẓar*; for a similar use of *naẓar* in Arabic see Dozy, 2:694.) The lacuna occurs where an insert (? of more recent origin) has been placed in the hole at the ecliptic pole and interferes with the inscription. The second inscription reads: "By order of (*bi-rasm*) the cabinet of treasuries (*khizānah*) of the Sulṭān al-Maṭṭ al-ᶜĀdil Ulugh Bēg." (*Al-Maṭṭ* [the proud] could, with some modification, be read as *al-malik* [the ruler].) The dates in the first two inscriptions are written out in words rather than in numerals; this in known to occur on only one other globe, where the inscription is in Persian (No. 33).

The star groups representing the lunar mansions have been placed near the ecliptic in geometrical patterns which show a reliance by the maker upon the cosmology of al-Qazwīnī or the occult writings of al-Būnī, both of the thirteenth century, or similar writings in which geometrical patterns are associated with the lunar mansions (see Savage-Smith & Smith, 40–41, Table 2). Holes are drilled at both the ecliptic and equatorial poles. The lines representing the ecliptic and equator are somewhat wobbly and the graduations rather uneven. The star positions near the ecliptic are so poorly placed that it is difficult to tell to what epoch they conform. If the date on the globe is considered correct, one must assume the last inscription to have been added later, since Ulugh Bēg lived in the fifteenth century.

A metal stand consists of three curving legs meeting at the bottom of a pedestal stand supporting two crossed semicircular arcs to which the horizon ring is attached. The horizon ring is engraved only with a line at every 30° interval; ungraduated meridian ring. Around the top of the pedestal support is a curious inscription which is transcribed in Chapter 8.

This is a technically non-functional and inaccurate globe which might possibly be of a more recent date of execution than that indicated in the inscriptions.

See Figures 7 and 8 for illustrations of the globe.

Exhibited in Paris in 1935 at the exposition *Instruments et Outils d'Autrefois*; no. 11 of catalog. In the Chadenat collection until May 1957, when it was sold at public sale in Paris.

Citations

Chadenat, item no. 42, plate XII (photograph).
Maddison [1957], 40, no. 181, photograph, on cover.
Mayer [1956], 31.
Destombes [1957], 320 no. 8.

61.

Location: Paris. Private collection of Marcel Destombes.
Date: 813 H [AD 1410–1411].
Maker: Muḥammad ibn Jaᶜfar al-Aṣṭurlābī.

Metal; hemispheres joined at ecliptic. Diameter 67.5 mm. No constellation figures; 35 stars indicated by inlaid silver points. Ecliptic latitude circles. Ecliptic and equator graduated by single degrees with every fifth labeled; ecliptic repeats every 30°; equator numbered continuously from vernal equinox. Zodiacal names engraved along ecliptic; equatorial poles and stars labeled; Kūfic. Holes have been drilled at both the ecliptic and

equatorial poles. The graduations are irregular and the precision not perfect. In the southern hemisphere beneath the houses of Sagittarius and Capricorn is the inscription, written without diacritical points, reading: "The work of (*ṣanʿat*) Muḥammad ibn Jaʿfar al-Aṣṭurlābī in the year 813 H." The date could also be interpreted as 818, 853, or 858 H, but the earliest date seems most likely in terms of other instruments made by him and by his father. The maker is the son of the maker of globes Nos. 7 and 8.

Stand and rings missing.

Formerly in the collection of M.A. Lee, this globe was sold in 1962 at Sotheby & Co., London. A detailed study of this globe is to be published by M. Destombes, who interprets the date (written in Kūfic *abjad* letters without diacritical points) as 803 H [AD 1400–1401].

Citation

Sale catalog of Sotheby & Co., London, dated 26 February 1962, p. 8. Plate IV has two photographs.

62.

Location: London. British Museum, Department of Oriental Antiquities; Inventory No. 26.3.23.

Date: 834 H, 805 Yazdijird, and 1733 Alexandrian era [AD 1430–1431].

Maker: Muḥammad ibn Jaʿfar ibn ʿUmar al-Aṣṭurlābī known as Ḥilāl.

Metal; hemispheres joined at ecliptic; dark finish. Diameter 105 mm. No constellation figures; about 60 stars indicated by inlaid silver points. Ecliptic latitude circles. Equator and ecliptic graduated by single degrees with every fifth labeled; ecliptic repeats every 30°; equator numbered continuously from vernal equinox. Zodiacal names engraved along ecliptic; stars and star groups labeled; Kūfic. Near the north equatorial pole there is the inscription: "The work of (*ṣanʿat*) Muḥammad ibn Jaʿfar ibn ʿUmar al-Aṣṭurlābī al-mulaqqab (known as) Ḥilāl." The last name can also be read as Jalāl since it is written without diacritical points. Near the south pole another inscription reads: "These stars were placed (*rusimat*) after increasing their longitude 7°5′ according to the *Constellations* of Abū al-Ḥusayn ibn ʿAbd al-Raḥmān al-Ṣūfī in the year 834 H, 805 Yazdijird, or 1733 of the Alexandrian Era." The year 1733 could be read as 1738 since there are no diacritical points. Holes have been drilled at both equatorial and ecliptic poles. Graduations are irregular and the precision not the best.

A slender metal pedestal stand is on a quadruped base formed by two intersecting semicircular arcs. The upper part of the pedestal supports two crossed semicircular arcs that hold the horizon ring, which is graduated by single degrees with every fifth labeled in non-consecutive segments of 90°, converging at the notches for the meridian ring. The ungraduated meridian ring is semicircular, covering only the top half of the globe; holes are placed in it at 5° intervals for different terrestrial latitude settings. One end of a chain is attached to one end of the meridian ring where it is joined to the horizon ring; the other end of the chain holds a pin which passes through the desired latitude hole in the meridian ring and the celestial north pole of the globe. Stand and rings appear contemporary with globe.

See Figure 10 for an illustration.

Citations

Mayer [1956], 68, with photograph of signature on plate XIIa.

Destombes [1957], 321, no. 10.

Destombes [1960], 206–207, no. 3; reads the Yazdijird date as 800 and prefers the reading of Jalāl to Ḥilāl; also states that the correct Alexandrian date would be 1743.

63.

Location: Chicago. Adler Planetarium and Astronomical Museum; Inventory No. A 114.

Date: 1012 [H] [AD 1603–1604].

Maker: Unsigned, but bears patron's name.

Metal; hemispheres with seam at ecliptic. Diameter 150 mm; weight 1389.1 grams. Only 12 figures representing the zodiacal houses are engraved; they are not actually constellation outlines but only decorative medallions. There are 38 stars indicated by inlaid silver points surrounded by a circle. Ecliptic latitude circles;

equatorial tropic and polar circles; ecliptic tropic circles; equinoctial colure and one circle 30° to the west passing through the equatorial poles (a meridian). There are also circles about 12° inside each of the tropic circles, parallel to both the ecliptic and equatorial tropic circles. Equator represented by a simple line with no graduations; ecliptic represented by the line of the seam. The figures representing the Houses are not the usual constellation figures (e.g., Libra is a cross-legged human figure holding the scales like a yoke over the shoulders) and there are no stars indicated in them; each figure is enclosed in a circle and is of a decorative style found on some other forms of Islamicate metalwork. Each medallion figure is labeled with the name of the zodiacal house outside the circle; equinoxes, solstices, ecliptic latitude circles, meridian, both colures, both sets of poles, ecliptic, equator, *mayl kullī*, tropic and polar circles are labeled; *naskhī* in floriated double-outlined writing on recessed stippled ground. A unique feature of the globe is a large crescent moon engraved on it between the north equatorial pole and the House of Aries. Within a cartouche located between the Houses of Aries and Pisces and the south ecliptic pole is an inscription reading: "By command of (*ḥasb al-amr*) the sulṭān of sulṭāns, the honorable and powerful Bandeh Shāh Walāyat ᶜAbbās, completed 1012." The patron was Shāh ᶜAbbās I, who ruled AD 1587–1629 (for the formula used for his title see Rabino di Borgomale, 32–33).

Globes No. 82 and 83 are very similar in design.

Stand and rings are missing.

See Figure 20 for an illustration.

Citations

May be the globe of diameter 150 mm referred to by Yonge, 83. Otherwise unpublished.

64.

Location: Cairo. Museum of Islamic Art. Inventory No. 15266.

Date: Not given.

Maker: Muḥammad Zamān.

Metal; hemispheres joined at ecliptic. Diameter 74 mm. No constellation figures; about 40 stars, which had probably been indicated by inlaid silver points that are now missing. Ecliptic latitude circles; equatorial tropic and polar circles; equinoctial colure. Equator and ecliptic graduated by 2° intervals with every tenth degree labeled; ecliptic repeats every 30°; equator is numbered continuously from vernal equinox. Zodiacal names engraved along ecliptic; equatorial north pole labeled and 36 stars labeled; *naskhī*. Near south poles it is signed: "The work of (*ṣanᶜat*) Muḥammad Zamān." Star positions relative to the equinoxes conform to the middle of the seventeenth century. Maker also made globes with constellations, Nos. 16 and 17.

Stand and rings missing.

Exhibited in Cairo in 1935 at an exposition of Persian art.

Formerly in Harari collection, no. 402.

Citations

Wiet [1939], 16, no. 35.
Mayer [1956], 79.

65.

Location: Baltimore, Maryland. Walters Art Gallery; Inventory No. 54.712.

Date: 1056 H, 1004 Yazdijird, and 1986 Alexandrian era [AD 1646–1647].

Maker: No signature.

Metal; hemispheres with seam passing through the ecliptic poles but not coinciding with any of the ecliptic latitude circles; very dark finish. Diameter 100 mm. No constellation figures; about 150 stars indicated by inlaid silver points. Ecliptic latitude circles. Ecliptic and equator graduated by single degrees with every fifth labeled; ecliptic repeats every 30°; equator numbered continuously from vernal equinox. Zodiacal names engraved along ecliptic; names of 28 lunar mansions engraved along ecliptic; ecliptic and equatorial poles and most stars labeled; *naskhī* tending toward *taᶜlīq*. Beneath the Southern Fish there is the Arabic inscription: "These stars were placed (*rusimat*) after increasing their longitude 4 [degrees] in accordance with the observatory of Samarqand in the year 1056 H, 1004 of the

Yazdijird era, and 1986 of the Alexandrian era." It is probable that 1956 was intended instead of 1986, which would involve a very slight alteration of the reading. The entire globe is badly corroded and the writing of the inscription rather crowded and not very clear. Holes have been drilled at both the ecliptic and equatorial poles. The precision of the placement of stars relative to the equinoxes is not consistent, but the majority correspond to the middle of the seventeenth century.

Stand and rings missing.

The globe was acquired from Kelekian by the Walters Art Gallery in 1928. It was exhibited in 1952 and 1955–1956 at the Walters Art Gallery (no. 20 in the catalog, "The World Encompassed," 7 October–23 November 1952, where it was listed as thirteenth century or later) and in 1955–1956 in Newark at the Newark Museum.

Citation

Yonge, 83 says it is undated but attributes it to the seventeenth century; a very short entry. Otherwise unpublished.

66.

Location: Patna (Bihar), India. Private Collection of Maulvi Yusuf Sahib in the Phulvari district (as of 1935).

Date: 1058 H. [AD 1648–1649].

Maker: Ḍiyāʾ al-Dīn Muḥammad ibn Qāʾim Muḥammad ibn Mullā ʿĪsà ibn Mullā Allāhdād Asṭurlābī Humāyūnī Lāhūrī.

Metal; no seam observable; one very large circular plug under signature. Diameter unknown; weight 567 grams. No constellation figures; about 20 stars indicated by rather large inlaid silver points. Ecliptic latitude circles; equatorial tropic and polar circles. Equator and ecliptic graduated by two degrees with every sixth labeled. Zodiacal names engraved along ecliptic; most of the stars labeled; *naskhī*. Signature near end of Eridanus reads: "The work of (*ʿamal*) Ḍiyāʾ al-Dīn Muḥammad ibn Qāʾim Muḥammad ibn Mullā ʿĪsà ibn Mullā Allāhdād Asṭurlābī Humāyūnī Lāhūrī in the year 1058 H." Although the stars are large in proportion to the globe, being about 4° in diameter, they appear to be positioned like those on other globes of the seventeenth-century Lahore workshop.

Metal quadruped stand on circular base with central pedestal support for the semicircular arc attached to underside of horizon ring. Outside edge of meridian ring graduated by 6° intervals, each of which is labeled; meridian ring contains holes for setting globe for different terrestrial latitudes.

Entry based on published statements and one photograph.

The family in Patna has owned the globe since AD 1822–1823 and it was still in their possession in 1935.

Citations

Nadvi [1935], 628 no. 1.
Klüber, 5 (photograph).

67.

Location: Paris. Private collection of Marcel Destombes.

Estimated Date: AD 1650 (not inscribed).

Maker: Luṭf Allāh ibn ʿAbd al-Qādir al-Muḥibb al-Asṭurlābī.

Metal; no seam observable; large circular plug 15 mm in diameter around north ecliptic pole; lead segregation evident. Diameter 67 mm. No constellation figures; 62 stars indicated by inlaid silver points. Ecliptic latitude circles; equatorial tropic and polar circles. Ecliptic and equator graduated by two degrees with every tenth labeled; ecliptic repeats every 30°, while equator is numbered continuously from vernal equinox. Zodiacal names engraved along ecliptic; ecliptic poles, equatorial poles, and stars labeled; rather crude *naskhī*. Inscription near north poles reads: "The work of (*ṣanʿat*) the weakest of servants Luṭf Allāh ibn ʿAbd al-Qādir al-Muḥibb al-Asṭurlābī, may God forgive his sins." Star positions conform to middle seventeenth century.

Quadruped metal stand with horizon ring. Meridian ring pierced so as to allow for the globe to be set at different terrestrial latitudes at intervals of 4°. Height of globe on stand 137 mm.

In the collection of M.A. Lee before being sold in 1962 at Sotheby & Co., London.

Citation

Sale catalog of Sotheby & Co., London, dated 26 February 1962, p. 8 no. 15.

68.

Location: Cambridge, England. Whipple Museum of the History of Science; Inventory No. 1255.
Date: 21 Shawwāl 1065 [24 August AD 1655].
Maker: Ḥāmid ibn Muḥammad Muqīm ibn ʿĪsà ibn Allāhdād Asṭurlābī Lāhūrī Humāyūnī.

Metal; no seam observable; one large plug of diameter 40 mm and several small dark plugs visible. Diameter 99.3 mm. No constellation figures; about 67 stars indicated by silver dots inlaid with indentations in the middle of each; one such silver dot is inlaid at each ecliptic pole. Ecliptic latitude circles. Ecliptic and equator graduated by single degrees with every fifth labeled; ecliptic repeats every 30° while equator is labeled in two segments of 180° each beginning at the equinoxes. Zodiacal names engraved along ecliptic; all stars and equatorial poles labeled; *naskhī*, rather poorly engraved with resulting mistakes. Maker's name and date inscribed near the southern equatorial pole: "*ṣnt* [an error for *ṣanʿat*, the work of] the unworthy servant (*qalīl al-ʿibād*) Ḥāmid ibn Muḥammad Muqīm ibn ʿĪsà ibn Allāhdād Asṭurlābī Lāhūrī Humāyūnī, written [*taḥrīr*, meaning the act of writing or composing, possible here in sense of engraving] on the date (*fī al-tārīkh*) the twenty-first of the month of Shawwāl of the year 1065." Star positions immediately along ecliptic indicate an epoch of about the second half of the seventeenth century, but those stars further from ecliptic are rather poorly positioned. The star at 5° House of Pisces (beneath the signature) was incorrectly labeled *dhanab al-qīṭus* (tail of Cetus) and re-engraved *sāq sākib al-māʾ* (shinbone of Aquarius). The latter star, *δ Aquarii*, is frequently found on astrolabes and on Class B globes even though it is not usually labeled on Class A globes.

See figure 14 for an illustration.

Stand and rings missing.

69.

Location: Cairo. Museum of Islamic Art; Inventory No. 3800.
Date: 1070 H [AD 1659–1660].
Maker: Ḍiyāʾ al-Dīn Muḥammad ibn Qāʾim Muḥammad ibn ʿĪsà ibn Allāhdād Asṭurlābī Humāyūnī Lāhūrī.

Metal; no seam observable; one square plug visible. Diameter 60 mm. No constellation figures; about 60 stars indicated by a dot enclosed in a small circle. Ecliptic latitude circles. Equator and ecliptic graduated by two degrees with every sixth labeled. Zodiacal names engraved along ecliptic; stars labeled; *naskhī*. Signature around south equatorial pole begins: "The work of (*ʿamal*) Ḍiyaʾ al-Dīn Muḥammad . . . . " Holes at both ecliptic and equatorial poles.

Metal horizon ring on metal quadruped stand, 92 mm high, on ring base. Meridian ring has labeled holes for setting at different latitudes. Probably contemporary with globe.

No further information recorded at time of examination.

70.

Location: Karachi. National Museum of Pakistan.
Date: Fourth of Ramaḍān 1083 [H] [25 December AD 1672].
Maker: Unknown.

Metal; no seam observable in photograph; one possible large circular plug. Diameter unknown. No constellation figures; about 50 stars indicated by small inlaid silver points. Ecliptic latitude circles; equatorial tropic and polar circles and circles 12° and 20° parallel to equator on both sides; equinoctial colure. Ecliptic (?and equator) graduated by 2° (?) intervals with every sixth degree labeled; ecliptic repeats every 30°. Zodiacal names engraved along ecliptic; most stars labeled; *naskhī* tending toward *taʿlīq*. Near the southern polar circle beneath the Houses of Sagittarius and Capricorn is a three-line inscription, the first line of which is nearly illegible in the photograph, only the word Muḥammad in the middle being legible. The other two lines read: "on the date (*fī tārīkh*) of the fourth of the month of Ramaḍān [in the] year 1083."

Three-legged metal stand with the S-curve legs being shaped in a leaf design and resting on rounded decorated feet. A semicircular arc attached to the underside of the horizon ring supports the globe; over the top of the globe is a

heavy, semicircular zenith ring, held in position by two wing-bolts at the sides of the horizon ring. The horizon ring is graduated by 2° (?) intervals with every sixth degree labeled in non-consecutive segments of 90° beginning at the notches holding the zenith ring and converging at the notches for the meridian ring; the outside edge of the top of the horizon ring is engraved in a decorative pattern. The meridian ring is also graduated by 6° intervals on the outside face. One half of the ring may be thinner than the other half, though it is difficult to tell from the photograph. The stand and rings appear to be contemporary with the globe.

The globe is probably Indo-Persian in origin. The stand and rings bear a striking similarity to those of No. 54 and No. 33, although the date of this globe is considerably earlier than those globes. On the other hand, the calligraphy of this maker resembles the poorly inscribed signature of No. 68 made by Ḥāmid ibn Muḥammad Muqīm of the Lahore workshop in 1065 H/AD 1655.

Entry based on a photograph taken by Simon Digby, formerly of the Ashmolean Museum; photograph now on deposit with the Museum of the History of Science, Oxford.

71.

Location: New Delhi. Red Fort Archaeological Museum.
Date: 1087 [H] [AD 1676–1677].
Maker: Ḍiyāʾ al-Dīn Muḥammad ibn Mullā Qāʾim Muḥammad ibn Ḥāfiẓ ʿĪsà ibn Shaykh Allāh-dād Humāyūnī.

Metal; no seam observable in available photographs; the three "inlaid patches" described by Kaye are probably plugs. Diameter 65 mm. No constellation figures; 92 stars indicated by a dot enclosed in a small circle. Ecliptic latitude circles; equatorial tropic and polar circles. Equator and ecliptic graduated by 2° intervals with every sixth degree labeled; ecliptic repeats every 30° while the equator repeats every 90°. Zodiacal names engraved along ecliptic; equatorial poles and 91 stars are labeled; *naskhī*. Signature around south equatorial pole beings: "the work of (*ʿamal*) the weakest of the servants (*aḥqar al-ʿibād*) Ḍiyāʾ al-Dīn . . . . " The name of the maker resembles that on globe no. 30 rather than his other products, in that the name, Ḥāfiẓ is added, Allāh-dād is written with different orthography, and Lāhūrī is omitted.

Heavy metal quadruped stand with straight six-sided legs on an eight-lobed ring base with center cross-bars holding a central pedestal support for the meridian ring. Horizon ring is graduated by 2° intervals with every sixth degree labeled in non-consecutive segments of 90° converging at the notches for the meridian ring which are also labeled north-south; names of the four cardinal points engraved near outer edge of horizon ring. There are also indentations on the top of the horizon ring at the zero points, apparently to accommodate a semicircular arc serving as a zenith ring, now missing. Ungraduated meridian ring is probably a recent replacement.

Entry based on published account and photographs in the files of A. Brieux and in the archives of G.R. Kaye, now at the Museum of the History of Science, Oxford.

Citations

Kaye [1921], 16–19, with photographs in figure 9 of plate II. Kaye makes several mistakes in transliteration.
Stone, 160.

72.

Location: Cairo. Museum of Islamic Art; Inventory No. 15364.
Date: 1215 [H]/[AD 1800–1801].
Maker: Muḥammad Ashrāf Tūqādī Zādah.

Painted wooden globe, or possibly painted ivory; brown ground with black lines and labeling; lacquered. Diameter 78 mm. No constellation figures; about 50 stars marked with a dot of black paint. Meridian circles cross the equator at 30° intervals; there are no ecliptic latitude circles. Equatorial and ecliptic polar and tropic circles. The circles parallel to the equator at 12° and 20° (as well as 24° which mark the tropics) north and south are prominently indicated. There is also a complete set in very fine ink lines of parallels at 2° intervals north and south of the equator, and a similar set at 2° intervals parallel to the ecliptic. The ecliptic and equator them-

selves are indicated by simple lines with small dots marking the 2° intervals with every 10° interval indicated by a short dash at right angles to the great circle. The zodiacal names are written along the ecliptic, the stars are labeled; small *naskhī* tending toward *ta^clīq*. Near the south celestial pole is the signature "The design of (*rasmat*) Muḥammad Ashrāf Tūqādī Zādah [in the] year 1215."

The rings and stand are clearly contemporary with this globe, for the stand has the signature "the work of (*ᶜamal*) Muḥammad Ashrāf 1215." The metal quadruped stand (72 mm high) is on a ring base bisected by a bar to which is attached a central support for the meridian ring. The horizon ring is graduated by 2° intervals with every tenth degree labeled in non-consecutive segments of 90° converging at the notches for the meridian ring; horizon ring has names of the four cardinal points engraved near outside edge; notches labeled north-south. The metal meridian ring is also graduated by 2° intervals with every tenth degree labeled in non-consecutive segments of 90° beginning at the points of attachment to the globe and converging near the equator. The pin running through the globe as an axis is connected to a small metal plate which is attached to the meridian ring at the north pole with a small screw.

Both globe and rings exhibit remarkable precision of design and execution. Perhaps the contrast between *ᶜamal* on the stand and *rasmah* on the globe indicated that Muḥammad Ashrāf actually constructed as well as graduated the metal rings and stand, but designed and executed the surface details of the globe onto a sphere that had been fashioned by another craftsman. Possibly Muḥammad Ashrāf also wished to make clear by the term *rasmah* that he himself designed the rather unusual style of the globe and that the design was not copied from another globe. Compare this intricate design with that of the anonymous globe No. 76.

Formerly in Harari Collection, No. 159.

Citation

Mayer [1956], 64.

73.

Location: Cairo. Museum of Islamic Art; Inventory No. 3774.
Dated: 23 Jumāda I, 1221 H [9 August AD 1806].
Maker: Muḥammad ᶜAlī al-Ḥusaynī.

Painted and lacquered *papier mâché* over hollow wood core. Diameter 234 mm. Globe painted with dark rich brown ground, red and black circles, black labeling, gilt stars, and red, black and gilt figures. Only 12 figures representing the zodiacal houses are depicted on the globe; they are not actual constellation outlines, but only small decorative figures, with no stars indicated in them. There are approximately 50 stars indicated by very large gilt dots, most of which are labeled. Ecliptic latitude circles; equatorial tropic and polar circles indicated by black circles. Equator and ecliptic each indicated by two red and one black parallel circles, graduated by single degrees with every fifth labeled; ecliptic repeats every 30°; equator numbered continuously from vernal equinox. Zodiacal names written along ecliptic; ecliptic latitude circles, poles, polar circles, and *mayl kullī*, and most stars labeled; *naskhī*. The *mayl kullī* is labeled *mayl kullī janūbī* (*shamālī*) *23 darajah wa 30 daqīqah wa 17 thānīyah* (southern [northern] greatest distance of ecliptic from equator is 23 degrees 30 minutes and 17 seconds). Holes at both ecliptic and celestial poles. Graduations are uneven and circles wobble slightly. The surface of the globe is not uniformly spherical. Calligraphy quite good. Technically non-functional and inaccurate, though star positions conform roughly to those of the beginning of the nineteenth century.

Between the south celestial pole and the zodiacal houses of Sagittarius, Capricorn and Aquarius is a long Arabic inscription which includes quotations from the Qurʾān whose identification I have noted in the translation:

Glory be to God, there is no god but He, Creator of the heavens and earth, Who placed in the sky the zodiac, and we adorned them for the beholders [Qurʾān XV,16] and the sun and the moon and the stars were made to pursue their course only by His authority, to Him belong creation and command. Praise be to God, Lord of the Worlds, that in the

difference of the night and the day there are signs [of His Sovereignty] for those of vision [Qurᵓān III,190]. Praise be to God the Best Creator. And the sun runs to a fixed resting-place that is the ordaining of the All-mighty and the All-knowing [Qurᵓān XXXVI,38] and the moon—we have determined it by mansions until it returns like an aged palm-tree bough [Qurᵓān XXXVI,39], that they might know the number of the years and the reckoning [Qurᵓān X,5] that in that are tokens [of His sovereignty] for those of understanding. Finished by the hand of (*tummat ᶜalà yad*) the hopeful [of God's mercy] and contrite servant [of God] Muḥammad ᶜAlī al-Ḥusaynī, supervisor of the teaching facilities, and on his master [? employer] a thousand salutations and praise. On Saturday, the twenty-third of Jumāda I, 1221 H.

The zodiacal figures are representative of a different iconographic tradition from that found on celestial globes on which the figures serve as outlines of the asterisms. The figures are reminscent of the Persian iconographic tradition depicted in the medallions of globes No. 63 and No. 83 and on other forms of Islamic metalwork, but also bear some resemblences to the zodiacal figures in the constellations pictured on globe No. 56, also of lacquered *papier mâché*.

Stand and rings missing.

74.

Location London. Victoria and Albert Museum, Department of Metalwork; Inventory No. M.24-1882.
Date: 1241 H and 1195 Yazdijird era [AD 1825–1826].
Maker: Muḥammad Karīm.

Metal; no seam observable; several plugs visible including large square plug around south equatorial pole; rattles slightly. Diameter 126 mm. No constellation figures; about 80 stars indicated by inlaid silver points which have tarnished and several of which are missing. Ecliptic latitude circles; equatorial tropic and polar circles. Ecliptic and equator graduated by single degrees with every sixth labeled; ecliptic repeats every 30°; equator is numbered continuously from vernal equinox. The solstitial colure is graduated by single degrees with every sixth indicated by a longer line and labeled every 6° in nonconsecutive segments of 90° beginning at the ecliptic and converging at the ecliptic poles. Zodiacal names engraved along ecliptic; names of the 28 lunar mansions engraved along ecliptic at intervals of about 12½° indicated by short lines; equatorial poles and most of the stars are labeled; *naskhī* tending toward *taᶜlīq*. Within the south equatorial polar circle there is the signature: "The work of (*ᶜamal*) Muḥammad Karīm [in the] year 1195 Yazdijird Solar (*shamsī*) era." Outside the polar circle there is the date, 1241 H. Star positions relative to the equinoxes conform to those of the late seventeenth or early eighteenth century. Executed with considerable precision.

Stand and rings missing.

Was acquired in India and given to the Victoria and Albert Museum in 1882.

Citation

Mayer [1956], 69.

75.

Location: Istanbul. Collection of Oduglü.
Date: 3 Rabīᶜ I 1299 [23 January AD 1882].
Maker: Ḥusayn Ḥüsnü Kanqarlī.

Metal; seam along equator; dented on one side. Diameter unknown. No constellation figures; about 100 stars indicated by relatively large engraved asterisks or circles with radiating lines. Ecliptic latitude circles; full set of meridians; equatorial tropic and polar circles. Equator and ecliptic graduated by single degrees with every fifth indicated by longer line. Along the ecliptic every 10° interval is labeled in *standard* numerals, repeating every 30°; every 10° interval of the equator is labeled in standard numerals, 10°, 20°, 30° . . . 180°, possibly proceeding continuously around the equator, although it may be labeled in two 180° segments, for it cannot be determined from the one available photograph. The names of the zodiacal houses and the numerals are written with the top of the writing toward the north poles—that is, in the reverse direction from that on all other known Islamicate globes. Among the star names are some constellation names; the majority of the stars are labeled; *naskhī*. The inscription in Ottoman Turkish between the north polar circle and the House of Cancer reads: "A student at the Normal

School, Ḥusayn Ḥüsnü Kanqarlī made (*ikhtira*ᶜ) this celestial globe (*kurah samāwī*) [in the] year 1229, the third of Rabīᶜ."

Stand and rings missing.

This is the only known example of an Ottoman Turkish celestial globe. While the circles are uniformily executed and the graduations of moderate precision, the star positions are imprecise and vary greatly in the epoch to which they conform.

Entry based on photograph and transcription of the inscription in the files of A. Brieux and F.R. Maddison.

Anonymous and Undated

76.

Location Damascus. Musée Nationale; Inventory No. A. 4485.

Painted paper on a wooden core; yellow, red, and black. Diameter 224 mm. No constellation figures; about 60 stars or star groups indicated by small circles with radiating lines, or by groups of such circles. Ecliptic latitude circles drawn in red; set of six meridians drawn in black; equatorial tropic and polar circles in black; ecliptic poles have small circles about 6° in diameter around them. Equator indicated by simple line; ecliptic graduated by single degrees with every fifth indicated by a short line extending on either side with dots at either end. Zodiacal names written in red along ecliptic; lunar mansions are for the most part written along ecliptic at regular intervals; directions and seasons written along equinoctial colure; most stars labeled; *naskhī* tending toward *ta*ᶜ*līq*. The equinoctial colure is graduated by single degrees with every fifth labeled in non-consecutive segments of 90° beginning at the equinoxes and ending at the poles. There is a network of half-great circles originating at the intersection of the celestial equator and the solstitial colure at the winter solstice and extending to the equinoctial colure at 5° intervals. The hemisphere thus defined is also covered by a series of parallels (parallel to equinoctial colure) at 1° intervals, drawn in red, with every 5° parallel drawn in black. The purpose of the network, perhaps unique on extant globes, is unclear.

The wooden horizon ring on a stand of four round and tapered legs on circular base with central support for meridian ring is contemporary with the globe. A geometrical floral pattern is on the base of the stand. The horizon ring is graduated near the inner edge by single degrees with every fifth labeled in non-consecutive 90° segments beginning at the points where the meridian ring is inserted. Every 30° is assigned a zodiacal house in counter-clockwise direction, the insertion of the meridian ring occurring between Gemini and Cancer (summer solstice) and Sagittarius and Capricorn (winter solstice). A circle of dots marks the separation between the zodiacal houses. Near the outer edge of the horizon ring is a table of place names arranged in pairs, one written in black and one in red. Six pairs of place names are aligned with each zodiacal house. From the available photographs, it was impossible to make out any but a few of the 144 localities on the horizon ring. Meridian ring is ungraduated (? a recent replacement).

Since the equator is indicated by only a simple line and the meridian ring is ungraduated, it is possible that this unusual network of half-great circles and parallels was intended as an aid to measuring the right ascension and declination of a star; the graduations of the equinoctial colure would supply the necessary scale for measuring the declination while the graduations along the equator, given by the intersections of the parallels along the southern half-circle of the equator, would serve as a scale for the right ascension measurement. In addition the parallels would delineate the intervals between the equinoxes. The celestial longitudes of the stars indicate an epoch of the end of the eighteenth century; the celestial latitudes of the stars, however, are in several instances quite poor. For example, Regulus (*qalb al-asad*) is on the summer tropic rather than the ecliptic, and the nineteenth lunar mansion, *al-shawlah*, is indicated near the equator rather than the ecliptic. There are some similarities in craftsmanship, calligraphy, and the precise execution of the circles and parallels be-

tween this globe and that made by Muḥammad Ashrāf Tūqādī Zādah in 1215 H/AD 1800–1801 (No. 72).

See Figure 28 for an illustration.

Displayed at the exhibition "Science and Technology in Islam" held at the Science Museum, London, as part of the Festival of the World of Islam, April–August 1976.

Entry based on photographs and information supplied by F.R. Maddison of the Museum of the History of Science, Oxford, who suggests that the unusual network of semi-great circles and parallels was intended for use in measuring the coordinates of the ecliptic, by placing the axis of the globe in a horizontal position and tilting it at an angle equivalent to the obliquity of the ecliptic.

Citation

Maddison & Turner, 83.

77.

Location: London (Greenwich). National Maritime Museum, Department of Navigation; Inventory No. G.3.36.379.

Metal hemispheres joined at equator. Diameter 70 mm; weight 370.8 grams including meridian ring (4.4 × 1.5 mm). No constellation figures; about 20 stars indicated by inlaid silver points. Ecliptic latitude circles; equatorial tropic and polar circles; ecliptic tropic circles. Equator and ecliptic graduated by 2° intervals with every tenth labeled; ecliptic repeats every 30°; equator numbered continuously from vernal equinox. Zodiacal names engraved along ecliptic; poles, tropic and polar circles, the *mayl kullī*, and stars labeled; *naskhī*. Positions of stars relative to the equinoxes conform to middle to late seventeenth century. Circles are precisely engraved, but graduations slightly uneven.

Metal pedestal stand on circular base with two crossed semicircular arcs supporting the globe and attached to the underside of the horizon ring. Horizon ring is graduated by two degrees with every tenth indicated by a longer line. Although the rings are graduated slightly more carefully than the globe, they appear to be contemporary with the globe.

78.

Location: London (Greenwich). National Maritime Museum, Department of Navigation; Inventory No. G.6.36.382.

Metal; hemispheres joined at equator with soldering evident; cracking visible; probably two cast hemispheres. Diameter 50 mm; weight 141.2 grams including axis rod of diameter 1.98 mm. No constellation figures; about 20 stars indicated by inlaid silver points. Ecliptic latitude circles; equatorial tropic and polar circles; equinoctial colure. Equator and ecliptic divided by 6° intervals (no single degrees) with every unit of 6° labeled. Numerals are written sideways rather than in the same direction as the zodiacal names. Ecliptic repeats every 30°; equator is numbered in *opposite directions* from the vernal equinox in two segments of 180°, one running eastward and one westward. Zodiacal names engraved along ecliptic; poles, tropic and polar circles and the *mayl kullī*, and stars labeled; *naskhī*. Positions of stars in relation to the equinoxes conform to the late seventeenth or early eighteenth century.

Three-legged stand on ring base with inverted semicircular arc attached to ring base to support the globe. Both the horizon ring and meridian rings are ungraduated. Non-functional.

79.

Location: London. The Victoria and Albert Museum; Inventory No. 1149-1883. Not assigned to any department.

Metal; hemispheres joined at equator. Diameter 82 mm. No constellation figures; about 20 stars indicated by inlaid silver points. Ecliptic latitude circles; equatorial tropic and polar circles. Zodiacal names engraved along ecliptic; ecliptic latitude circles, solstitial colure, and some stars labeled; *naskhī*. Ecliptic and equator graduated by single degrees with every sixth labeled; ecliptic repeats every 30°, equator numbered continuously from the vernal equinox. Positions of stars in relation to equinoxes conform to middle of seventeenth century.

Metal quadruped stand, one leg of which is missing, on eight-lobed ring base with center

crossbars in the center of which is a pedestal support with a semicircular arc to support the globe attached to underside of horizon ring at the notches for the zenith ring; zenith ring is missing. Horizon ring graduated by 5° intervals labeled in non-consecutive segments of 90° converging at the notches for the meridian ring. Meridian ring is graduated by 5° intervals labeled in non-consecutive segments of 90° beginning at the points of attachment to the globe. Although the stand and rings appear to be about the same age as the globe, they may not have originally been made for this globe, since they are graduated with a different scale and the precision is not good.

80.

Location: Oxford. Museum of the History of Science, Billmeir Collection; Inventory No. 57-84/184.

Metal; has a rough large seam at equator with soldering visible. Diameter 79 mm; weight 355 grams. No constellation figures; about 20 stars indicated by inlaid silver points. Ecliptic latitude circles; equatorial tropic and polar circles; equinoctial colure. Ecliptic and equator graduated by 2° intervals with every tenth degree labeled; ecliptic repeats every 30°; equator is numbered continuously from the vernal equinox. Zodiacal names engraved along ecliptic; poles, tropic and polar circles and stars labeled; *naskhī*. Very few stars are near ecliptic, but their positions generally conform to the late seventeenth century. A pin passes through the equatorial poles with a ring by which it can be suspended.

Stand and rings missing.

Citation

Maddison [1957], 41, plate XXVIII (photograph).

81.

Location: Oxford. Museum of the History of Science, Billmeir Collection; Inventory No. 57-84/182.

Metal; there is a seam along ecliptic which can be felt from inside, although no seam is observable on outside; several cracks; probably two cast halves. Diameter 131 mm; weight 599 grams. No constellation figures; 37 stars indicated by engraved dots within circles. Ecliptic latitude circles; equatorial tropic and polar circles, and a full set of circles parallel to the ecliptic at 5° intervals on both sides of the ecliptic. Has the unique feature of having arcs drawn and labeled through a star (labeled *ᶜayyūq, α Aurigae*) indicating the different coordinate systems. The semi-great-circle representing the declination circle (*dāʾirat mayl*) is marked by a dotted line, while the arc on which the celestial latitude is measured (*dāʾirat ᶜarḍ*) is an engraved solid line. In addition, there is engraved and labeled on the surface of the globe a circle corresponding to the horizon ring (*dāʾirat ufq*), another for the meridian ring (*dāʾirat niṣf al-nahār*), along with the arc representing the prime vertical (*dāʾirat awwal sumūt*), the circle passing through the zenith and intersecting the horizon circle at the east-west points. The great circle passing through the zenith and the ecliptic poles is also indicated. Equator and ecliptic graduated by single degrees with every fifth labeled; ecliptic repeats every 30°; equator numbered continuously from vernal equinox; stars are given numbers corresponding to their magnitudes. In addition to the labels already mentioned, the zodiacal names are engraved along the ecliptic, and the poles, tropic and polar circles, solstitial colure, solstices, and the *mayl kullī* are labeled; *naskhī*. The engraving was not always carefully executed, with several circles redrawn; solstitial colure was incorrectly drawn and labeled as passing through the ecliptic at 15° House of Cancer, which the maker then noted was an error before labeling the correct circle. The accuracy of the star positions and graduation is good, however. By having the horizon rings indicated directly upon the surface of the globe, the coordinate systems indicated are valid for only one particular geographical latitude, in this case 32° north, which corresponds to the latitude of Yazd (or roughly that of Lahore). Star positions relative to the equinoxes conform roughly to those of the early seventeenth century. Because of the method of construction (two cast hemispheres), it is likely that this sphere of unusual design is a Ṣafavid product of a seventeenth-century workshop in or near Yazd.

See Figure 22 for an illustration.

Stand and rings missing, if indeed they were intended to be used with a globe meant to demonstrate the coordinate systems directly upon its surface.

Formerly in Chadenat Collection until May of 1956, when it was sold at a public sale in Paris.

Citations

Chadenat, item no. 44.
Maddison [1957], 40, No. 182, plate XXVIII (photograph).

82.

Location: London (Greenwich). National Maritime Museum, Department of Navigation; Inventory No. G.142. NA 9022-40C.

Metal; hemispheres with seam along ecliptic. Diameter 180 mm; weight 926.6 grams. Twelve zodiacal figures are engraved in circular medallions; these are not actually constellation outlines but only decorative devices. About 20 stars indicated by inlaid silver points. Ecliptic latitude circles; equatorial tropic and polar circles. Equator and ecliptic indicated by simple line and seam of globe; no graduation. Zodiacal medallions, poles, circles, and some stars labeled; *naskhī* in floriated double-outlined writing on recessed stippled ground. Stars are poorly positioned and without graduations it is impossible to tell to which epoch it was intended to conform.

A technically non-functional globe, but executed with first-rate calligraphy and well-drawn medallion figures by a very skilled metalworker. The figures representing the zodiacal houses are not the usual constellation figures, and there are no stars indicated in them. They are representative of a different iconographical tradition to be seen also on globes Nos. 63 and 83. This globe is strikingly similar in nearly every respect to that made for Shāh ᶜAbbās I in 1012 H/AD 1603–1604 (No. 63).

Probably a Ṣafavid Persian product of the early seventeenth century.

Has a six-legged metal stand with horizon and meridian rings very inaccurately graduated by approximate 1° intervals with every sixth indicated by a longer line. Not contemporary with globe.

83.

Location: Cambridge, England. Whipple Museum of the History of Science; Inventory No. 1410.

Metal; seam along ecliptic. Diameter 121 mm. No constellation figures but 12 zodiacal figures engraved in circular medallions. About 42 stars (unlabeled) indicated by inlaid silver points sometimes having circles engraved around them. Ecliptic latitude circles; incomplete set of meridians consisting of equinoctial colure and one 30° to the west; equatorial and ecliptic tropic circles; circles about 12° inside each of the tropic circles parallel to both the ecliptic and equatorial tropic circles; equatorial polar circles. Ecliptic and equator ungraduated. Zodiacal houses labeled outside medallions; ecliptic, equator, equinoxes, solstices, the *mayl kullī*, ecliptic latitude circles, meridians, tropic circles, polar circles, equatorial and ecliptic poles labeled; *naskhī* tending toward *taᶜlīq*. Along the ecliptic are 12 circular medallions with the zodiacal figures which represent a different iconographic tradition from true constellation diagrams. It is very similar in this respect to globes Nos. 82 and 63. The unlabeled stars are spaced regularly about the globe, resulting in little if any astonomical accuracy.

The globe is probably of Ṣafavid Persian origin of the early seventeenth century.

The globe is placed in a meridian ring and horizon ring with stand which are not contemporary with the globe and of a different alloy. The horizon ring, supported by three tapered legs on a ring base, has approximate 5° segments numbered in an irregular and scrambled sequence, with irregular smaller divisions. The meridian ring, also marked with irregular divisions and disordered numerals, is mounted at the equatorial poles of the globe and permanently attached to the horizon ring with the axis of the globe parallel to the horizon.

84.

Location: London (Greenwich). National Maritime Museum, Department of Navigation; Inventory No. G.26.36.384.

Metal; no seam observable; one plug visible; rattles when shaken for it has a white pebble in

it which is larger than the bored holes. Diameter 60 mm; weight 236.5 grams including meridian ring (1.75 × 3.8 mm). No constellation figures; about 20 stars indicated by inlaid silver points. Ecliptic latitude circles; equatorial tropic and polar circles; equinoctial colure. Ecliptic and equator graduated by 6° intervals (not single degrees) with each 6° segment labeled; ecliptic repeats every 30°; equator repeats every 90°. Zodiacal names engraved along ecliptic; names of the 28 lunar mansions engraved on opposite side of ecliptic at intervals of about 12° indicated by a short line; stars labeled; *naskhī*. Precisely made globe. Star positions in relation to the equinoxes conform generally to those of the seventeenth-century Lahore workshop.

Metal quadruped stand, with central square knob on each leg, on a ring base. A semicircular arc attached to underside of horizon ring supports globe; in the center of the arc there is an indentation with a hole bored through it that must have been used with a pin to secure the meridian ring. The horizon ring is graduated by 2° intervals with every sixth labeled in non-consecutive segments of 90° converging at the notches for the meridian ring. Meridian ring ungraduated; later replacement.

85.

Location: (Greenwich) London. National Maritime Museum, Department of Navigation, Inventory No. G.5.36.381.

Metal; no seam observable nor felt inside; three plugs visible including two about 10 mm in diameter on opposite sides of globe along the equator; dull finish. Diameter 80 mm; weight 408.1 grams. No constellation figures; about 20 stars indicated by inlaid silver points. Ecliptic latitude circles; equatorial tropic and polar circles; equinoctial colure. Ecliptic and equator graduated by single degrees with every sixth labeled; ecliptic repeats every 30°; equator numbered in two 180° segments. Names of zodiacal houses engraved along ecliptic; names of the 28 lunar mansions engraved along ecliptic at intervals of about 12° indicated by short lines; stars labeled; *naskhī*. A well executed and precise globe. Star positions relative to the equinoxes generally conform to those of the seventeenth-century Lahore workshop.

Quadruped metal stand, with squarish knobs having decorative notches on top, center and bottom of each leg, on circular base. There is no undersupport for the globe. Globe does not set far enough down in the ring for it to function properly. Hence stand useless. Both horizon ring and meridian ring are ungraduated and not contemporary with globe.

86.

Location: Oxford. Museum of the History of Science, Lewis Evans Collection; Inventory No. 2913.

Metal; no seam observable outside nor felt inside; two plugs visible; slight dent; dull dark finish. Diameter 100 mm; weight 376 grams. No constellation figures; 57 stars indicated by small engraved ×s. Ecliptic latitude circles; equatorial tropic and polar circles. Ecliptic and equator graduated by 2° intervals with every sixth degree labeled; ecliptic repeats every 30°; equator numbered continuously from vernal equinox. Zodiacal names engraved along ecliptic; stars labeled; *naskhī*, tending toward *taᶜlīq*. The engraved labels and the ×s indicating the stars have been whitened to stand out against the dark surface of the globe. Several holes have been drilled in the globe, possibly at a later date. There are holes at both the ecliptic and equator and at about 25° on either side along the solstitial colure (compare globes No. 7 and No. 8). Quite precise and uniform graduation. The star positions relative to the ecliptic generally conform with those of the seventeenth-century Lahore workshop.

Metal quadruped stand with S-curve legs shaped in a leaf design and resting on rounded feet. A semicircular arc attached to the underside of the horizon ring supports the globe. Horizon ring graduated by two degrees with every sixth numbered in non-consecutive segments of 90° converging at the notches for the meridian ring. Meridian ring is graduated by 2° intervals with every sixth labeled in non-consecutive segments of 90°. One half of the ring (from zero-point to zero-point) is thicker than the other semicircle and is nearly flush against the surface of the

globe. Under the thinner half of the ring there rotates a thin 90° arc rather carelessly graduated by single degrees which is attached at the midpoint, or 90° label, of the thinner half-circle. At the zero-points on either side of the ring are two protruding lips that should rest on the horizon ring to hold the meridian ring immobile. The stand is made so that the thicker part (labeled on the lower right-hand quadrant "southern latitude") must be at the bottom to fit in the stand properly. The pin holding the graduated rotating arc would therefore always be at the top or zenith and could serve to measure the altitude, and the axis of the globe could be adjusted to different terrestrial latitudes by inserting it through the appropriate set of holes drilled through the meridian ring. There are holes labeled for northern geographical latitudes of 21°, 24°, 32°, 48°, 66° 30′, and for southern latitudes of 21° (approximate, for unlabeled), 24°, 29°, and 72°. Labeling has been whitened to stand out against the dark finish of the stand and rings, as on the globe. A long, decorative pin serves as axis for the globe; this pin does not pass freely through the holes labeled 72° and 24° south and 21° north.

Stand and rings contemporary with globe. The stand and horizon ring are strikingly similar to those of globe No. 70 (made in 1083 H/AD 1672 and also to the later globes Nos. 33 and 55. The design of the meridian ring is very similar to that of No. 18 made by Ḍiyāʾ al-Dīn Muḥammad of the Lahore workshop in 1055 H/AD 1645–1646.

Probably an Indo-Persian product, possibly of the seventeenth-century Lahore workshop.

Globe was bought from Sayyid Bahadur Shah in Lahore by H. Beveridge and later sold to Lewis Evans. Displayed at the exhibition Science in India held at the Science Museum, London, March–August 1982.

Citation

Anderson, 34, no. 125.

87.

Location: Present location unknown.

Metal; no seam observable; two large circular plugs of diameters 27 and 28 mm opposite each other, one below the House of Aquarius and Pisces and the other above the Houses of Leo and Virgo; walls appear to be very thick. Diameter 75.2 mm; weight 610 grams. No constellation figures; about 60 stars indicated by engraved dots within small circles. Ecliptic latitude circles; equatorial polar circles; equatorial tropic circles and circles 12° either side of equator. Ecliptic and equator graduated by 2° intervals with every sixth labeled; ecliptic repeats every 30°, while equator is numbered in two segments of 180° each. Zodiacal names engraved along ecliptic; celestial poles and nearly all stars labeled; *naskhī*. Holes at both ecliptic and equatorial poles. The graduations are somewhat uneven and the distances between circles are not uniform. Star positions conform in general to those of middle to late seventeenth century, although the latitude of some stars is irregular. A technically inaccurate and imprecise globe, probably of seventeenth-century Indo-Persian origin.

Quadruped stand on ring base, with center knob of three rings with two rings at top and bottom on each leg. Semicircular arc attached to underside of horizon ring supports the globe. Horizon ring graduated by irregular divisions of more or less 1° with every fifth labeled in nonconsecutive segments of 90° beginning at the notches for the meridian ring. Meridian ring missing. Stand not contemporary with globe.

Entry based on photographs and information obtained from F.R. Maddison of the Museum of the History of Science, Oxford.

Formerly in a private collection in France. Offered for sale at Christie's auction house in 1982 (Christie's reference no. CQ 314).

88.

Location: Oxford. Museum of the History of Science, Billmeir Collection; Inventory No. 57-84/183.

Metal; no seam observable outside nor detectable inside; no plugs visible on outside, but stumps for casting visible inside; has appearance of a soft, heavily leaded alloy with possible lead segregation evident; rattles. Diameter 76 mm; weight 344 grams. No constellation figures; 22 stars indicated by inlaid silver points. Ecliptic latitude circles; equatorial tropic and polar cir-

cles; equinoctial colure. Ecliptic and equator graduated by 2° intervals with every sixth degree labeled; ecliptic repeats every 30°; equator also repeats every 30°. Zodiacal names engraved along ecliptic; stars labeled; *naskhī*. Graduations and circles precisely engraved. Positions of stars relative to the equinoxes are not consistent, for those near autumnal equinox seem to conform to those of early seventeenth century while those around the vernal equinox appear to conform to the late seventeenth century. A rod passes through the equatorial poles with end bent at each end to form small hooks by which it might be suspended.

Stand and rings missing.

Formerly in Chadenat Collection until May, 1956, when it was sold in Paris.

Citations

Chadenat, item no. 45.
Maddison [1957], 41, no. 183, plate XXVIII (photograph).

89.

Location: London. The Science Museum, Department of Astronomy and Geophysics; Inventory No. 1914-597. Lent by the Royal Astronomical Society.

Metal; no seam observable; three large plugs and seven small black squares about 2 mm across are visible; rattles; dark finish which appears very blotchy and discolored in irregular patches. Diameter 140 mm. No constellation figures; about 150 stars indicated by large inlaid silver points, each within an engraved circle. Ecliptic latitude circles; equatorial tropic circles in dotted engraving; ecliptic and equatorial polar circles in dotted engraving; equinoctial colure with dotted engraving. Ecliptic and equator graduated by single degrees with every sixth indicated by dotted lines and labeled; ecliptic repeats every 30°; equator is numbered continuously from vernal equinox. Zodiacal names engraved along ecliptic; poles, polar circles, both colures, equinoxes and stars labeled; *naskhī*. Graduations and circles precisely inscribed. Positions of stars in relation to the equinoxes conform to those of late seventeenth century. Modern threaded insert has been put into equatorial poles.

Meridian ring is labeled and graduated by single degrees with every sixth labeled in non-consecutive segments of 90°. One semicircle from zero-point to zero-point is nearly flush against the surface of globe. The other semicircle is recessed from the globe surface so as to allow for a rotating 90° arc to be attached at the midpoint, or 90° label; this arc is now missing, although the pin to hold it is still intact. This semicircle of the meridian ring also extends out past the edge of the other half-circle so as to rest securely on the horizon ring and hold the ring immobile. In this position the rotating arc would serve to measure altitude, and the globe could be adjusted to a given terrestrial latitude by setting the axis of the globe through one of the holes in the meridian ring. In the ring, in addition to holes at the zero-points (equivalent to the equator), there are holes for northern latitudes labeled of 24°, 27°, 32°, 51°, and 66°30′, and for southern latitudes of 18°, 29°, 35°, and 72°. The numbers of the lower half of the circle, which should always be below the horizon ring if properly positioned, are written with the bottom of the numerals toward the outside of the ring, while the bottom of the numerals on the upper half are turned to the inside of the ring. In this way, both semicircles can be easily read in this stationary position. The point where the pin for the now missing arc is inserted is labeled *nisf al-nahār* (midday). Meridian ring is contemporary with globe and is very similar in design to the rings of globes Nos. 18 and 86. The quadruped wooden stand, with wooden ring which does not actually serve as a true horizon ring, is recent and non-functional.

Citations

Rothman [1840].
Rothman [1842]; lists some of the stars labeled on the globe and attributes it to the eighteenth rather than the seventeenth century.
Calvert, 2 (photograph).

90.

Location: Rockford, Illinois. The Time Museum; Inventory No. 1175.

Metal; no seam observable inside or outside; 8 small round plugs visible; a very large circular

hole at the north equatorial pole where probably a large plug was once placed. Diameter 184 mm; wall thickness 2.5 mm. No constellation figures; 32 stars indicated by inlaid silver points and numbered and labeled. Ecliptic latitude circles; six meridian circles intersect the equator at 24°, 54°, 84°, 114°, 144°, 174°, 204°, 234°, 264°, 294°, 324°, and 354° (there is no meridian circle representing the equinoctial colure); equatorial tropics; two parallel circles at 12° and 20° from the equator on both sides. Ecliptic and equator graduated by single degrees with every sixth indicated by a longer line and labeled; ecliptic repeats every 30°; equator numbered continuously from vernal equinox. Zodiacal names engraved along ecliptic; south equatorial pole and stars labeled; *naskhī* tending toward *taᶜlīq*. Stars are numbered with standard numerals. All circles and graduations were lightly traced on the globe first and then engraved over more deeply. Small silver points are inlaid at the equinoxes and ecliptic poles and the points of intersection of the meridians with the equator. Very accurate and uniform graduations and circles. Positions of the stars relative to the equinoxes conform to those of the middle of the nineteenth century.

The unusual design (with a set of six meridians shifted 6° westward), the engraving technique of the circles and graduations, the calligraphy, the great precision, and the star positions are so similar to those of globe No. 33 made by Lālah Balhūmal Lāhūrī in AD 1842 that with considerably certainty this globe can be attributed to Lālah or to someone trained in his workshop.

For an illustration see Figure 26.

Stand and rings now missing.

Citation

Turner (in press).

CLASS C—GLOBES WITH NEITHER STARS NOR CONSTELLATIONS

Signed or Dated

91.

Location: Chicago. Adler Planetarium and Astronomical Museum; Inventory No. A 116.

Date: 1238 [H] [AD 1822–1823].

Maker: Muḥammad Samᵓī Tarī.

Metal; no seam observable; no plugs visible. Diameter 102 mm; weight 411.1 grams. No constellation figures and no stars. Ecliptic latitude circles; equatorial tropic and polar circles; equinoctial colure (with the ecliptic latitude circle intersecting the equinoctial colure omitted). Ecliptic and equator indicated by simple lines with no graduations. Zodiacal names engraved along ecliptic; tropic and polar circles, solstices, solstitial colure, the *mayl kullī*, ecliptic, equatorial poles, equinoxes, and solstices labeled; *naskhī*, written with floriated double-outlined writing on dark recessed ground with a band around each inscription, except for the cartouche near the vernal equinox in which the date and name of maker are given. The latter is lightly engraved with a stippled background; possibly added later. The inscription in the cartouche could be interpreted in several ways, perhaps reading: "the work of (ᶜ*amal*) Muḥammad Samᵓī Tarī in 1238." The top part of the cartouche seems to read *bandah mubarrā* (a freed slave), though this is by no means clear. Globe is probably of Persian origin.

Stand and rings missing.

92.

Location: London: The Victoria and Albert Museum, Indian Section; Inventory No. 06,475 (I.S.).

Date: 1241 H [AD 1825–1826].

Maker: Unsigned, but bears patron's name.

Metal; hemispheres joined at equator. No constellation figures and no stars. Diameter 100 mm. Ecliptic latitude circles; equatorial tropic and polar circles; equinoctial colure. Ecliptic and equator indicated by simple lines with no graduations. Zodiacal names engraved along ecliptic; poles, tropic and polar circles, the *mayl kullī*, solstices, and equinoxes labeled; *naskhī* tending toward *taᶜlīq*. Inscription, which appears to be in same hand as rest of globe, reads: "Its owner is (*mālikuhu*) Nawāb Muḥammad ᶜAlī Khān Ṣāḥib [in the] year 1241 H." It was probably made for Nawāb Muḥammad ᶜAlī Khān (also called Madali Khān), the eighth Khān of Khokand, who ruled

in Khokand in Transoxania from AD 1822–1842. It has been suggested by the Victoria and Albert Museum that the globe was made in Oudh in India, but this does not seem as likely.

Meridian ring graduated irregularly by single degrees with every sixth indicated by a longer line; mounted to equatorial poles of globe. Stand and horizon ring missing.

Anonymous and Undated

93.

Location: Oxford. Museum of the History of Science; Inventory No. 69-186.

Painted *papier mâché* and plaster over some kind of fiber core; tan ground with black ink circles and red ink lettering; lacquered; in deteriorated condition. Diameter 178 mm, weight 907.2 grams including brass meridian ring and axis rod. Ecliptic latitude circles; meridian circles through the equatorial poles every 60° beginning with equinoctial colure; equatorial polar and tropic circles; parallel circles 1° inside each tropic and 4° inside each tropic, the latter two labeled "The Circle of the Start of Gemini and Virgo/Aquarius and Sagittarius." Equator and ecliptic graduated by single degrees with every tenth labeled; ecliptic repeats every 30°; equator is numbered continuously from vernal equinox. Zodiacal names written along ecliptic, each name being enclosed in a double circle; poles, tropic and polar circles, the *mayl kullī*, equinoxes, and solstices labeled; *naskhī*. A precisely executed globe. Since it has no stars, the globe's date cannot be estimated according to precession, as is the case with all globes in this category; probably seventeenth or eighteenth century.

Ungraduated metal meridian ring, not contemporary with globe. Stand and horizon ring missing.

See Figure 27 for an illustration.

94.

Location: Oxford. Museum of the History of Science, Billmeir Collection; Inventory No. 57-84/30.

Papier mâché on wooden core, painted and lacquered; tan, brown, and gilt paints with black ink labels; rattles. Diameter 70 mm; weight 57 grams. No constellation figures and no stars.

Ecliptic latitude circles; equatorial tropic and polar circles; equinoctial colure. Equator and ecliptic indicated by simple lines with no graduations; circles in gilt paint. Zodiacal names written along ecliptic; the *mayl kullī*, solstices, solstitial colure, equinoxes, equator, equinoctial colure, ecliptic latitude circles, poles, and tropic and polar circles labeled; *naskhī*, tending toward *ta*ʿ*līq*. Some Persian words mixed with the Arabic; where the *mayl kullī* are labeled the obliquity of the ecliptic is given as 23°30′ (*mayl kullī kah janūbī* (*shamālī*) *23 wa nīm*).

Wooden meridian ring with every interval equal to 5° labeled in non-consecutive segments of 90° beginning at the two points where it is attached to the equatorial poles of the globe. Pin with a hook for suspension of globe passes through the meridian ring and celestial poles of globe; horizon ring missing.

Formerly in the collection of M. Henri Michel.

Citation

Josten, 21.

95.

Location: Present location unknown.

Metal; no plugs visible; appears to have a seam along equator; badly scratched surface. Diameter unknown. No constellation figures and no stars. Ecliptic latitude circles; equatorial tropic and ecliptic tropic circles (except both sets of tropics are drawn about 5° too far away); also a circle about 20° on either side of both ecliptic and equator; equinoctial colure. Equator ungraduated and represented by seam (?), while ecliptic graduated rather crudely into single degrees with every tenth labeled, repeating every 30°. At various places on the globe the lunar mansions are named, but no stars are indicated. Zodiacal names are written in bold double-outlined writing in circular medallions along ecliptic; lightly incised; *naskhī*. Graduations uneven and circles poorly spaced.

Metal meridian ring has only one half of ring graduated; this semicircle is graduated by single degrees with every fifth labeled both in *abjad* numerals and standard numerals in non-consecutive segments of 90° converging at the midpoint. The graduated half of the ring appears to be wider than the ungraduated half. and to rest on the surface of the horizon ring. The globe is at present mounted at the zero-points; there may be holes in the ring for various terrestrial latitudes, although this is not visible in the available photograph. There is a metal horizon ring supported by four short legs, with knob centers, about the height of the radius of the globe, which in turn rest on another ring of the same size which is supported by four rounded feet; it is not known if the horizon ring is graduated. There appears to be no central undersupport for the meridian ring and globe; however, if the ring were of the type which is stationary, with the graduated semicircle resting immobile on the horizon ring, the meridian ring would support the weight of the globe and an undersupport would be unecessary. It may be that this ring and horizon ring are not contemporary with the globe, since the globe seems to have been very badly scratched possibly by a very close fitting meridian ring, while the present meridian ring is a considerable distance from the surface of the globe.

Entry based on the photograph in the sales catalog when it was offered for sale in Paris in 1977.

Citation

C. Boisgirard—A. de Heekeren, Instruments Scientifiques Anciens, Le jeudi 28 Avril 1977, Salle No. 8: Expert: Alain Brieux (sale catalog, Item no. 669).

96.

Location: Present location unknown.

Metal; no plugs visible; appears to have a seam at equator. Diameter unknown. No constellation figures and no stars. Ecliptic latitude circles; equinoctial colure; both equatorial and ecliptic tropic circles; both equatorial and ecliptic polar circles, with two outer circles about 5° and 10° distant concentric with each. Ecliptic and equator graduated unevenly by single degrees with every fifth labeled; ecliptic repeats every 30° while equator is numbered continuously from vernal equinox. Names of zodiacal houses engraved in double-outlined writing in small circular medallions; the *mayl kullī* and poles labeled; *naskhī.*

Ungraduated meridian ring. The horizon ring and stand are clearly not contemporary with globe for they do not fit the globe properly. The horizon ring is graduated by single degrees with every fifth labeled (pattern not discernible); a semicircular undersupport for the globe and ring is attached to the underside of the horizon ring and terminates in a large finial. The horizon ring is supported by four very tall slender legs having central square knobs and X-shaped decorations; the height of the legs is about one and a half times that of the diameter of the globe; these legs in turn rest upon a ring the same size as the horizon ring. This lower ring has decorative palmettes on the upper surface and is supported by four rounded feet. The horizon ring and stand may be Indo-Persian while the globe may be a Persian product.

Entry based on a photograph in the files of F.R. Maddison, sent to him by Saeed Motamed of Frankfurt am Main sometime in the 1960s.

97.

Location: Paris. Private collection.
Maker: Unsigned; but bears patron's name.

Metal; no seam observable; no plugs visible. Diameter 69 mm; height on stand 141 mm. No constellation figures and no stars. Ecliptic latitude circles; equatorial tropic and polar circles; equinoctial colure. Ecliptic and equator graduated by 2° intervals with every tenth degree labeled; ecliptic repeats every 30° while equator is numbered continuously from the vernal equinox. Zodiacal names written in large double-outlined writing along ecliptic; *mayl kullī* labeled and probably some of the circles; *naskhī.* Graduations somewhat uneven and circles wobble slightly.

Meridian ring is graduated rather unevenly by

single degrees with every fifth indicated by a longer line, but with each larger interval labeled as if it were 6°: that is, it is labeled 6, 12, 18, etc., even though only 5° are actually indicated in each interval, in non-consecutive segments of 90° beginning at the points of attachment to the globe. The horizon ring is graduated but the pattern cannot be discerned from the photograph; to the underside of the horizon ring is attached a semicircular arc for supporting the globe which terminates in a four-sided finial. The horizon ring rests on four four-sided legs which in turn rest on a ring the same size as the horizon ring; at the tops, bottoms and centers of each of the long straight legs are square knobs. The bottom ring of the stand is engraved with an inscription in four parts, which names the patron, reading:

Suitable for the salon of His Excellency, the most learned savant of the ages, *mujtahad** of the era and the time, the Imām of the Muslims, drawing together the derivative institutes of the law and the fundamentals, combining sciences based on reasoning and transmitted knowledge,† the model of distinguished men, the glory of scholars, Mīrzā Muḥammad Taqī Khaṭarāt, may his efforts endure.

Ring and stand contemporary with globe.

Entry based on photograph and description from a sale catalogue when it was sold in Paris in 1976, and from a photograph in the files of A. Brieux and F.R. Maddison.

Citation

Histoire des sciences. Livres-Instruments (sales catalog). Alain Brieux. Paris. June 1976. (Item 8551, p. 74).

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* Shīʿite authority in religious jurisprudence.

† Jurisprudence, theology, cosmology, reports (*ḥadīth*) of the Prophet.

98.

Location: Paris. Private collection of Marcel Destombes.

Metal; seam along equator; no plugs visible, quite light in weight; perhaps raised hemispheres; badly damaged and dented. Diameter 67.6 mm. No constellation figures and no stars. Ecliptic latitude stars; equatorial tropic and polar circles; equinoctial colure. Ecliptic and equator graduated by 2° intervals with every tenth labeled. Ecliptic repeats every 30°; equator is numbered continuously from vernal equinox. Zodiacal names engraved along ecliptic in broad double-outlined writing; poles labeled; *naskhī*. Circles well drawn and graduations uniform and precise.

Stand and rings missing.

99.

Location: Vienna. Private collection of R. Schmidt (as of 1963).

Metal; no seam observable; no plugs visible. Diameter unknown. No constellation figures and no stars. Ecliptic latitude circles; equatorial tropic and polar circles; ecliptic tropic circles; equinoctial colure (poorly drawn so that it does not pass properly through the equinoxes). Ecliptic and equator graduated by 2° intervals with every tenth degree labeled; ecliptic repeats every 30° while equator is numbered continuously from the vernal equinox. Zodiacal names along the ecliptic, the polar circles and the *mayl kullī* are labeled in large double-outlined writing; equatorial tropic circles and equinoctial colure labeled in regular script; *naskhī*. Graduations are uneven and the circles wobble, and the intersections of ecliptic and equator are poorly executed.

The meridian ring is graduated rather unevenly in 2° segments with every sixth degree indicated by a longer line and labeled in non-consecutive segments of 90° beginning at the points of attachment to the globe. The horizon ring is graduated unevenly by single degrees with every fifth indicated by a longer line, but with each larger interval labeled as 6° (just like the meridian ring on globe No. 97) in non-consecutive segments of 90° beginning at the two notches for the meridian ring. To the underside of the horizon ring is attached a semicircular arc supporting the globe which terminates in a four-sided finial. The horizon ring rests on four four-sided legs, which in turn rest on a ring the same size as the horizon ring. At the tops, bottoms, and centers of each of the long straight legs are

square knobs. Stand and rings appear to be contemporary with globe.

The design and execution of the globe, stand, and rings is so nearly identical to globe No. 97 that it is very likely by the same marker.

Entry based on six photographs in the files of the Museum of the History of Science, Oxford.

100.

Location: Oxford. Museum of the History of Science; Inventory No. 2901.

Metal; no seam observable; no plugs visible, but seam can be felt inside along ecliptic; dull dark brown mottled finish which has been applied to globe and which in one spot has been rubbed off. Diameter 89 mm; weight 186 grams. No constellation figures and no stars. Ecliptic latitude circles; equatorial tropic and polar circles; ecliptic tropic and polar circles; equinoctial colure. Ecliptic and equator graduated by 2° segments with every tenth degree labeled; ecliptic repeats every 30°; equator is numbered continuously from vernal equinox. Zodiacal names along ecliptic and the *mayl kullī* are labeled in large double-outlined writing; the polar circles, tropic circles, and equinoctial colure are labeled in regular script; *naskhī*. Where the *mayl kullī* is labeled, the obliquity of the ecliptic is also given (23°30′) in *abjad* numerals. There are holes at the ecliptic poles and a very small hole at the north equatorial pole. Appears to have been mounted on an axis at the southern ecliptic pole, for the surface has been rubbed by a circular plate about 45 mm in diameter centered at the south ecliptic pole. Graduations rather uneven and circles wobble slightly.

Stand and rings missing.

101.

Location: Chicago. Adler Planetarium and Astronomical Museum; Inventory No. A 39.

Metal; no seam observable; no plugs visible; rattles. Diameter 69 mm; weight 127.6 including brass meridian ring. No constellation figures and no stars. Ecliptic latitude circles; equatorial tropic and polar circles; ecliptic tropic and polar circles; equinoctial colure. Ecliptic and equator graduated by 2° intervals with every tenth degree labeled; ecliptic repeats every 30°; equator numbered continuously from vernal equinox. Zodiacal names engraved along ecliptic; poles, equatorial tropic and polar circles, and the two *mayl kullī* labeled; *naskhī*. Some of the engraving is in broad double-outlined writing and some is filled in in white. Graduations are uneven and circles somewhat wobbly.

Metal quadruped stand on ring base with top, center and bottom square knobs on the straight legs. The semicircular support under the globe attached to horizon ring has a screw at bottom that can tighten to hold meridian ring in place. Horizon ring graduated by 2° intervals with every sixth degree labeled in non-consecutive segments of 90° beginning at notches for meridian ring. Meridian ring graduated by 2° intervals with every sixth labeled in non-consecutive 90° segments beginning at the poles where it is attached to the globe by a pin. Rings and stand appear contemporary with globe.

Citation

Yonge, 80; brief entry with no inventory number.

102.

Location: Chicago. Adler Planetarium and Astronomical Museum; Inventory No. A 38.

Metal; no seam observable; no plugs visible; rattles. Diameter 70 mm; weight 134.7 grams including metal meridian ring. No constellation figures and no stars. Ecliptic latitude circles; equatorial tropic and polar circles; ecliptic tropic and polar circles; equinoctial colure. Ecliptic and equator graduated by 2° intervals with every tenth degree labeled; ecliptic repeats every 30°; equator numbered continuously from the vernal equinox. Zodiacal names engraved along ecliptic; poles, equatorial tropic and polar circles and the two *mayl kullī* are labeled; *naskhī* with some large double-outlined writing. Graduations and circles uneven.

Metal quadruped stand on ring base with hex-

agonal knobs at the top, center, and bottom of each tall straight leg. The semicircular support under globe attached to horizon ring has a very large wing-headed screw at the bottom (midpoint), which can tighten to hold meridian ring in place; the semicircular support terminates in a four-sided finial at midpoint. Horizon ring graduated by 2° intervals with every sixth degree labeled in non-consecutive segments of 90° beginning at notches for meridian ring. Meridian ring graduated by 2° intervals every sixth degree labeled in non-consecutive segments of 90° beginning at the points where it is mounted to the globe by a pin. Stand has been repaired. Probably contemporary with globe.

Is similar to preceding globe (No. 101), but engraving not quite as well executed.

Citation

Yonge, 80; very brief entry.

103.

Location: Oxford. Museum of the History of Science, Billmeir Collection; Inventory No. 57-84/186.

Metal; no seam observable outside but seam can be felt from inside to be along equator; no plugs visible; probably of two raised hemispheres; rattles. Diameter 88 mm; weight 172 grams. No constellation figures and no stars. Ecliptic latitude circles; equatorial tropic and polar circles; ecliptic tropic and polar circles; equinoctial colure. Equator and ecliptic graduated by two degrees with every tenth labeled; ecliptic repeats every 30°; equator is numbered continuously from vernal equinox. Zodiacal names engraved along ecliptic in double-outlined writing; *naskhī*. Graduations are uniform, but some circles are slightly uneven; generally a precise example of this style of globe.

Metal quadruped stand on ring base with top, center, and bottom square knobs on the straight four-sided legs. Semicircular support for globe is attached to the underside of the horizon ring. Horizon ring graduated by 2° intervals with every sixth degree numbered in non-consecutive segments of 90° beginning at the notches for the meridian ring; meridian ring also graduated by 2° intervals with every sixth degree labeled in non-consecutive segments of 90° beginning at points where attached to celestial poles of globe. Probably contemporary with globe.

Formerly in collection of C. Chadenat until 1956, when it was sold at public sale in Paris.

Citations

Chadenat, item no. 48.
Maddison [1957], 41, no. 186, plate XXVIII (photograph).

104.

Location: London (Greenwich). National Maritime Museum, Department of Navigation; Inventory No. G.176.36.377.

Metal; no seam observable; no plugs visible; noticeably light weight. Diameter 62 mm; weight 149.8 grams including metal meridian ring. No constellation figures and no stars. Ecliptic latitude circles; equatorial tropic and polar circles; ecliptic tropic and polar circles; equinoctial colure. Equator and ecliptic are graduated by 2° intervals with every tenth degree labeled; ecliptic repeats every 30°; equator is numbered continuously from vernal equinox. Zodiacal names engraved along ecliptic in double-outlined writing; poles, equinoctial colure, solstices, the two *mayl kullī*, tropic and polar circles labeled; *naskhī*. Circles wobble slightly, but graduations are even.

Metal quadruped stand on ring base with top, center, and bottom square knobs with triangular decorations on each four-sided straight leg. A semicircular support for globe is attached to underside of horizon ring and terminates at midpoint in a four-sided finial. Horizon ring graduated by 2° intervals with every sixth degree labeled and enclosed in a scalloped design in non-consecutive segments of 90° beginning at the notches for the meridian ring. Meridian ring undergraduated; probably a recent replacement.

105.

Location: Oxford. Museum of the History of Science, Billmeir Collection; Inventory No. 57-84/185.

Metal; no seam is visible, but seam can be felt from inside to be along equator; no plugs visible;

dented and rippled surface. Diameter 68 mm; weight 80 grams. No constellation figures and no stars. Ecliptic latitude circles; equatorial tropic and polar circles; equinoctial colure. Equator and ecliptic indicated by simple lines with no graduations. Zodiacal names written along ecliptic; *naskhī*. Circles wobble slightly.

Metal quadruped stand on ring base, with top, center, and bottom square knobs on each straight leg. Horizon ring graduated by 2° segments with every sixth degree labeled in non-consecutive segments of 90° beginning at the notches for the meridian ring. A semicircular arc attached to underside of the horizon ring supports the globe and terminates at midpoint in a four-sided finial. Horizon ring and stand may be contemporary with globe and closely resemble those of globes No. 97 and No. 99. Meridian ring appears to be of later construction; graduated by 2° segments with every sixth degree numbered in non-consecutive segments of 90° beginning at the points where it is attached to the celestial poles of the globe.

Formerly in the collection of C. Chadenat until 1956, when sold at public sale in Paris.

Citations

Chadenat, item no. 47.
Maddison [1957], 41, no. 185, plate XXVIII (photograph).

106.

Location: Present location unknown.

Metal; seam clearly visible in photograph. Diameter 69 mm. No constellation figures and no stars.

Has a meridian ring and an horizon ring which rests on four thin legs, with a square knob at top, center, and bottom of each leg; the four legs in turn rest on a ring base. The semicircular undersupport for the globe is attached to the underside of the horizon ring and terminates in a finial.

No further information available. Entry based on the short description in a sale catalog when it was offered for sale in Zurich in 1975.

Citation

La collection Greppin: Instruments scientifiques, Galerie Koller, Zurich, 1975 (sale catalog). Item no. 3137, p. 37; preceding plate I is a color illustration of a large number of the instruments grouped together, among which is this globe.

107.

Location: London (Greenwich). National Maritime Museum, Department of Navigation; Inventory No. G.2. NA. 9038-36.

Metal; seam along equator; dented. Diameter 95 mm; weight 220.3 grams including metal meridian ring (5.0 × 3.1 mm). No constellation figures and no stars. Ecliptic latitude circles; equatorial tropic and polar circles. Ecliptic and equator graduated by single degrees with every fifth indicated by a longer line. Zodiacal names engraved along ecliptic; poles, tropic and polar circles, equator and ecliptic labeled; *naskhī*. Circles wobble slightly.

Ungraduated horizon ring on quadruped stand 116 mm high; the central support for the globe has broken off. Ungraduated meridian ring.

Formerly in collection of Sir James Caird.

108.

Location: Philadelphia. Private collection of Mr. and Mrs. David H.H. Felix; Inventory No. B.

Metal; hemispheres joined at equator. Diameter 72 mm. No constellation figures and no stars. Ecliptic latitude circles; equinoctial colure; equatorial polar and tropic circles and parallel circles about 12° and 20° either side of equator and also two parallel circles about midway between tropics and polar circles (the latter may be the same as those circles on globe No. 112 that are 43° from the equator and tangent to the ecliptic polar circle at the solstitial colure). Zodiacal names engraved along ecliptic; equator, ecliptic, parallel circles, the two *mayl kulli*, and the poles labeled; *naskhī*, tending toward *ta^clīq*. Ecliptic and equator graduated by single degrees with every sixth labeled. Probably a seventeenth- or eighteenth-century Persian product.

Meridian ring, possibly contemporary with globe, graduated by uneven single degrees with every sixth labeled in non-consecutive segments of 90° beginning at the points of attachment to

the globe and converging at points opposite the celestial equator. The *abjad* numerals are not written with the bottoms of the letters toward the inside of the ring, which is customary, but rather with the letters turned sideways with the bottoms pointing toward the two points labeled 90°. Horizon ring missing.

Exhibited at the Philadelphia Museum of Art in 1977.

Entry based on photographs and information supplied by owners.

109.

Location: Philadelphia. Private collection of Mr. and Mrs. David H.H. Felix; Inventory No. A.

Metal; hemispheres joined at equator with soldering visible; dented. Diameter 55 mm: height with stand 174 mm. No constellation figures and no stars. Ecliptic latitude circles; equinoctial colure; equatorial tropic circles and parallels about 12° and 20° from equator; equatorial polar circles. Zodiacal names engraved along ecliptic; some circles labeled; *naskhī*. Ecliptic and equator graduated by single degrees with every sixth labeled.

Meridian ring missing. Horizon ring of different alloy and calligraphy. Ring supported by four very tall legs with four oblique notches cut in each leg, which rest on a ring in turn supported by four short slender legs; there appears to be no undersupport for the globe and meridian ring, even though there are two notches in the ring to allow a meridian ring to pass through. Horizon ring has the four cardinal points labeled and is graduated unevenly by single degrees with every fifth labeled in non-consecutive segments of 90° beginning at the notches (labeled north-south) and terminating at the east-west points. At present the pin passing through the axis of the globe rests horizontally on the horizon ring.

Exhibited at the Philadelphia Museum of Art in 1977.

Entry based on photographs and information supplied by owners.

110.

Location: Bloomfield Hills, Michigan. Cranbrook Institute of Science; Inventory No. T-29.

Metal; seam along equator. Diameter 100 mm. No constellation figures and no stars. Ecliptic latitude circles. Zodiacal names engraved along ecliptic; the two *mayl kullī* labeled; *naskhī*. Several tears and irregular holes less than 5 mm across are along the equator, which have been repaired with plugs of a different alloy soldered into place. Ecliptic and equator ungraduated. Holes 8 mm in diameter at equatorial poles.

Four short S-curve heart-shaped legs support a ring base which in turn supports a quadruped stand for the ungraduated horizon ring. The upper legs are decorated in a twisted rope design. To the underside of the horizon ring is attached a semicircular cradle for holding the globe and meridian ring. Meridian ring is graduated into 36 unlabeled intervals of 10° each; each interval has a hole through which the pin passing through the axis of the globe can be set. In this manner the globe may be rotated by 10° increments to indicate equivalent changes in terrestrial latitude.

Bought by the Institute in 1944 from Count Walewski.

Entry based on information and photographs supplied by the Institute.

Citation

Yonge, 86; very brief entry.

111.

Location: Present location unknown.

Metal; of silvered alloy; it is a noticeably heavy globe; no seam observable; one plug visible. Diameter 89 mm; weight 1450 grams. No constellation figures and no stars. Ecliptic latitude circles; equatorial tropic and polar circles. Equator and ecliptic indicated by simple lines with no graduation. Zodiacal names engraved along ecliptic; celestial poles, equinoxes, and solstices labeled; *naskhī*, tending toward *taʿlīq*; script filled with yellow coloring and rather poorly formed.

Metal, ungraduated meridian ring attached by screws to globe. Ungraduated metal horizon ring supported by three straight legs attached to a lower ring, which in turn is supported by three S-curve legs. Rings are held in place by metal screws with flat heads.

Probably an Indo-Persian product of the nineteenth century.

Acquired from a dealer in Bombay. Offered for sale in April of 1982 at a public auction in Paris.

Citation

Collection de l'ancienne Maison Gasselin, Instruments de chirurgie humain et vétérinaire . . . instruments scientifiques anciens (sale catalog). Nouveau Drouot, Salle No. 8, 28 Avril 1982. Commissaires-Priseurs: J. Lenormand and P. Dayen. Commissaires-Priseurs, SCP: E. Libert and A. Castor. Expert près les Douanes: Alain Brieux. (Item no. 90).

112.

Location: Present location unknown.

Metal; may have a seam along equator; no plugs visible in the only available photograph. Diameter 110 mm. No constellation figures and no stars. Ecliptic latitude circles; equatorial tropic circles; two parallel circles at 12° and 20° from the equator in both hemispheres; ecliptic and equatorial polar circles; in each hemisphere there is also a circle parallel to equator at about 43° from the equator that is tangent to the ecliptic polar circle at the solstitial colure. Ecliptic consists of a narrow band with very crude graduations of approximately one degree with every tenth, roughly, marked with a short dash outside the band and labeled, repeating every 30°; equator consists of a similar narrow band numbered every sixth degree continuously from vernal equinox. Zodiacal names engraved along ecliptic; the equinoxes, solstices, the *mayl kullī*, and every parallel circle are labeled; *naskhī*. Graduations crude and uneven; circles wobble slightly.

Metal meridian ring has crude graduations of approximately single degrees with every sixth labeled in non-consecutive segments of 90° beginning at the points of attachment to the globe. The horizon ring appears to be graduated and labeled, but pattern cannot be discerned from the photographs. The horizon ring is supported by a semicircular arc attached to the underside which also supports the globe. A tapered and turned pedestal stand holds the semicircular arc at its midpoint; the pedestal stand rests on a circular plate with scalloped upturned edges.

Entry based on photograph and description in the sale catalog when it was offered for sale in Paris in 1977, and also on an earlier photograph published in 1970.

Citations

Instruments scientifiques anciens (sale catalog). 28 Avril 1977, Salle no. 8. Commissaires-Priseurs: C. Boisgirard, A. De Heekeren. Expert près les Douanes: A. Brieux. (Item no. 668).

What appears to be the same globe was illustrated earlier by Guye & Michel, 210, plate 200. It is said to be in a private collection in Paris.

113.

Location: Paris. Private collection of Alain Brieux.

Metal; no seam observable; one plug visible. Diameter 112 mm; height on stand 190 mm. No constellation figures and no stars. Ecliptic latitude circles; equatorial tropic and polar circles; ecliptic polar circles. Ecliptic and equator graduated by single degrees with every fifth labeled; ecliptic repeats every 30°; equator is numbered continuously from vernal equinox. The solstitial colure is also graduated by single degrees with every fifth indicated by a longer line; space is left for numbering the larger intervals, but it has not been filled in. Zodiacal names engraved along ecliptic; equatorial poles labeled; *naskhī*. Graduations are uneven, and the circles are not all evenly drawn and appear to have been incised lightly twice before the final deep engraving. The alloy seems to have been very soft. Holes at both equatorial and ecliptic poles.

The outside face of the meridian ring is graduated somewhat unevenly by single degrees with every fifth labeled in non-consecutive segments

of 90° converging at the points of attachment to the globe. Horizon ring is also graduated, although pattern cannot be determined from available photographs. To the underside of horizon ring is attached a semicircular arc to support the globe. The horizon ring is supported by four slender octagonal legs resting on an eight-lobed ring based with central cross-bars. Stand and rings appear to be contemporary with the globe.

See Figure 34 for an illustration.

Entry based on photograph and description in the sale catalog when it was offered for sale in Paris in 1979, and on a photograph supplied by the owner.

Citation

Instruments scientifiques anciens médicine, chirurgie, curiosités medicales: Important Collection de Lunettes . . . Instruments de Mathematiques, d'astronomie, de gnomonique . . . (sale catalog). Drouot Rive Gauche Salle No. 16, 22 Juin 1979. Commissaires-Priseurs, SCP: E. Libert et A. Castor. Expert près les Douanes: A. Brieux (item 155 with photograph).

114.

Location: Present location unknown.

Metal; no seam observable; two small brown plugs about 1 mm in diameter are visible. Diameter 84 mm; weight 500 grams. No constellation figures and no stars. Ecliptic latitude circles; equatorial tropic circles; ecliptic and equatorial polar circles; equinoctial colure. Ecliptic and equator graduated by single degrees with every sixth degree labeled and indicated by dotted circles. The equator is numbered in two 180° segments, while the ecliptic repeats every 30°. The equinoctial colure, tropic circles and polar circles are indicated by dotted circles. Zodical names engraved along ecliptic; polar circles, tropic circles, the two *mayl kullī*, the equinoctial colure are labeled; *naskhī*. The graduations are uneven, but the circles are quite well engraved; the sphere itself is very even spherically, and an example of quite good metalwork. The sphere has a slight musical rattle, and when the meridian ring is removed and a probe or the axis pin inserted inside, the globe at first appears to be a solid sphere. In fact there is an axial tube inserted between the two celestial poles through which the pin passes which is connected with the meridian ring; this tube is then lapped over at each end at the poles and hammered back over the surface of the sphere.

The rings and stand appear to be contemporary with the globe itself and of the same alloy. The meridian ring is on one side graduated by single degrees with every sixth labeled in non-consecutive segments of 90°, and on the other side by 6° intervals (no single degrees) labeled in the same manner. In two opposite quadrants there are holes for the north terrestrial latitudes (labeled) of 21°, 24°, 32°, and 66° 30′, while in the other two opposite quadrants, labeled "southern latitude" are holes for the latitudes of 18°, 24°, 29°, 34°, 40°, and 72°. The pin passing through the axis of the globe can be adjusted to one of the latitudes, keeping the zero-points of the ring, at which there are also holes, steady on the horizon ring. The horizon ring is attached to a quadruped stand on ring base with top, center, and lower hexagonal knobs on each leg; stand has later soldered repairs. The horizon ring is graduated by single degrees with every sixth labeled in non-consecutive segments of 90° converging at the notches for the meridian ring; there is a semicircular support for globe attached to the underside of the horizon ring.

Probably Indo-Persian, possibly nineteenth century.

Formerly in a collection in Great Neck, New York. Offered for sale on 10 December 1981 by Sotheby Parke Bernet & Co., London.

Citation

Watches . . . Scientific Instruments . . . Barometers . . . Clocks . . . which will be sold by auction by Sotheby Parke Bernet & Co. (sale catalog). Day of Sale 10 December 1981. Item no. 22, photograph p. 10.

115.

Location: Oxford. Museum of the History of Science, Billmeir Collection; Inventory No. 57-84/27.

Metal; no seam observable nor to be felt inside; eight plugs visible. It has a greenish-brown mot-

tled finish; one slight dent; rattles. Diameter 103 mm; weight 565 grams with meridian ring. No constellation figures and no stars. Ecliptic latitude circles. Equatorial tropic and polar circles; equinoctial colure. Simple lines indicate ecliptic and equator with no graduations. Zodiacal names engraved along ecliptic; poles, tropic and polar circles, and the two *mayl kullī* labeled; *naskhī.* Circles slightly uneven.

Metal meridian ring graduated by 2° intervals with every sixth indicated by a longer line on one side of ring, while on other side every 30° is marked by a longer line. Horizon ring is graduated by 2° intervals with every sixth indicated by a longer line. Four slender straight legs on an eight-lobed ring base support the horizon ring. Four concave arcs are also attached at one end to the ring base and meet together at the other ends and are attached to the midpoint of the semicircular arc which holds the globe and is attached to the underside of the horizon ring. Under what would be the east-west points of the horizon ring are two pointed devices which are markedly like the gnomons found on three early globes (Nos. 3, 4, 6). They are positioned over the curved supports in just the same manner as these early globes, but, like globe No. 4, the concave surface of the leg is not graduated.

Citation

Josten, 20. He attributes it to the sixteenth century or earlier; such an early date is unlikely; it is probably a middle to late seventeenth-century Indo-Persian product.

116.

Location: Baghdād. ᶜIraqī Museum; Inventory No. 9718.

Metal; no seam observable from photograph; no plugs visible. Diameter ca 97 mm. No constellation figures and no stars. Ecliptic latitude circles, ecliptic and equator all indicated by engraved double lines filled with hatch marks. Equatorial tropics engraved as well as, in the northern hemisphere, parallel circles approximately 4°, 8°, 12°, and 20° from the equator. Ecliptic and equator graduated by 10° segments (not single degrees) labeled; ecliptic repeats every 30° while equator is numbered continuously from vernal equinox. Zodiacal names engraved along ecliptic; solstitial colure and the two *mayl kullī* labeled; *naskhī.* Circles wobbly and poorly positioned.

Metal meridian ring graduated with a fair amount of regularity by single degrees with every fifth labeled in non-consecutive segments of 90° beginning at the two points opposite the celestial equator and terminating at attachments to the globe. Horizon ring and stand missing.

Exhibited at the exhibition "Science and Technology in Islam" held at the Science Museum, London, as part of the Festival of the World of Islam, April—August 1976.

Entry based on photographs in the files of the Museum of the History of Science, Oxford, and information supplied by F.R. Maddison and A.J. Turner.

Citation

Maddison & Turner, 87.

117.

Location: Present location unknown.

Metal; probably no seam observable, for catalog entry says "turned from a hollow casting." Diameter 79 mm. Ecliptic latitude circles; equatorial, tropic, and polar circles. Equator graduated by single degrees, represented by dots, with every fifth indicated by a long line (and possibly labeled); ecliptic similarly graduated. Zodiacal names engraved along ecliptic; various labels.

Stand and rings missing.

Entry based on description in sale catalog when offered for sale in London in 1957 (no photograph published). Following the sale, it was for a while in the collection of Landau.

Citation

Sotheby & Co. sale catalog; London, sale of Thursday, 14 March 1957. Item no. 150, p. 28.

118.

Location: Present location unknown.

Metal; diameter 125 mm. No constellation

figures and no stars. Ecliptic latitude circles; equinoctial colure. Equator and ecliptic indicated by simple lines with no graduations. Zodiacal names engraved along ecliptic; *naskhī*. Definite information not available as to whether or not it bears a maker's name or date or whether a seam is visible.

Metal quadruped stand with graduated horizon and meridian rings.

Entry based on the one short published description and photograph.

Citation

Schmidt, 23–24; photograph plate X.

119.

Location: Present location unknown.

Metal; diameter 79 mm. No constellation figures and no stars. Ecliptic latitude circles; polar circles, equator and ecliptic. Many Arabic inscriptions.

Stand and rings missing.

Formerly in collection of C. Chadenat.

Entry based on short description in sale catalog when offered for sale in Paris in 1956. This globe could possibly be the same as the globe No. 117.

Citation

Chadenat, item no. 46.

120.

Location: London. Private collection.

"A brass celestial globe, possibly Indo-Persian, engraved with divisions of the ecliptic and various great circles, with meridian ring. 86 mm diam., 18th century."

No further information available; Entry is quoted from sale catalog when it was offered for sale in London in 1972.

Citation

Sotheby & Co. (sale catalog). London, sale dated 24 July 1972.

121.

Location: Present location unknown:

Metal; diameter 132 mm. Ecliptic latitude circles; polar circles; ecliptic and equator. Numerous Arabic inscriptions. Supported by a modern baluster shaft on a round base with horizon and meridian rings. Height of support 320 mm.

In the collection of C. Chadenat until 1956, when it was sold at a public sale in Paris.

No further information available; entry based on sale catalog.

Citation

Chadenat, item no. 50.

122.

Location: Present location unknown.

Metal; diameter 82 mm. No constellation figures and no stars. Ecliptic latitude circles; tropic and polar circles, ecliptic and equator, all inlaid with silver. The twelve zodiacal names and the poles [?] are deeply engraved (*gravés en creux*). Stand and rings missing. No further information available.

In collection of Ch. Chadenat until 1956, when it was sold at public sale in Paris.

Citation

Chadenat, item no. 49.

123.

Location: Present location unknown.

Metal; diameter 90 mm. Engraved with inscriptions. Supported by a quadruped stand on a base with a central ring and crest supporting the meridian ring and the horizon ring which are graduated by three degrees. Height of stand 97 mm. No further information available.

In collection of C. Chadenat until 1956, when it was sold at a public sale in Paris.

Citation

Chadenat, item no. 52.

124.

Location: Present location unknown.

Metal. No constellation figures and no stars. Diameter 72 mm. "Engraved with zodiacal and planetary [*sic*] names, numerals and various circles." Stand has graduated horizon ring with names of four cardinal points. Height of globe on stand, 185 mm. "Eastern Islamic. 18th century."

No further information available; entry based on sale catalog.

In the collection of M.A. Lee, until 1962, when it was sold at Sotheby & Co., London.

Citation

Sotheby & Co., London (sale catalog). Sale dated 26 February 1962. Item no. 14, p. 7. The catalog adds: "Some of the circles engraved on the globe do not appear to be meaningful and the inscriptions contain errors."

Insufficient Information to Classify

Signed or Dated

125.

Location: Cairo: Was in private collection of Hasan bey Yazdi as of 1935.
Dated: 1040 H [AD 1630–1631].
Maker: Unsigned.

Metal. *Naskhī* script. Date engraved near south pole in small cursive writing.

Shown in exposition of Persian art in Cairo in 1935.

No futher information available.

Citation

Wiet [1935], 16, no. 34.

Unsigned and Undated

126.

Location: Glasgow. Collection of Arthur Frank, housed at Charles Frank Ltd., 145 Queen Street.

Persian celestial globe. No further information available.

Exhibited at the Glasgow Art Gallery and Museum, April–June 1973.

Citation

Nuttall, 44; attributed globe to about AD 1450.

Addendum to the Catalog

Class A—Celestial Globes with Constellations

127.

Location: Karachi, Pakistan. National Museum; Inventory No. N.M. 1957.1049.
Date: AD 1842, 1258 H and 1899 Vikrama era.
Maker: Lālah Balhūmal Lāhūrī.

Metal; no seam observable; one large plug visible near autumnal equinox. Diameter 177.8 mm. Full set of constellation figures with about 1018 stars indicated by inlaid silver studs. Ecliptic latitude circles; six meridian circles intersecting equator at 24°, 54°, 84°, 114°, 144°, 174°, 204°, 234°, 264°, 294°, 324°, 354° (there is no meridian circle representing the equinoctial colure); equatorial tropics; two lesser circles at 12° and 20° from equator on both sides of equator; equatorial polar circles. Ecliptic and equator graduated by single degrees with every sixth degree indicated by longer line and labeled; ecliptic repeats every 30°; equator has each 6° segment labeled with one numeral (1, 2, 3, 4 . . . 60) numbering continuously from vernal equinox. Zodiacal names engraved along ecliptic; constellations labeled; major stars labeled and all stars numbered within a constellation; *naskhī*, tending toward *ta*ᶜ*līq*. Graduations and circles precisely executed. Near the south pole is an inscription which states that it was made by Lālah Balhūmal Lāhūrī for the education of the son of one Khushi Ram in 1899 Vikrama era, 1258 H and AD 1842.

Modern, non-functional quadruped stand attached to south equatorial pole.

See No. 33 of the catalog for another globe by the same maker executed in the same year. Entry based on the one published photograph and short

description, where maker is referred to as Lala Balhooljee Sahib of Lahore.

Citation

Ashfaque, 222–223, no. 37 and plate VIIB.

128.

Location: Granada, Spain. Museo de la Alhambra.

A lacquered *papier mâché* (?) globe with constellations.

129.

Location: Present location unknown.

Painted wooden globe with constellations and stand. Diameter 130 mm; height on stand 255 mm. In 1977 was in the possesion of H.P. Kraus of New York.

Class B—Celestial Globes without Constellations

130.

Location: Karachi, Pakistan. National Museum; Inventory No. N.M. 1958.210.

Metal. Diameter 82 mm. No constellation figures; unknown number of stars indicated. Great circles indicated. Zodiacal names engraved along the divisions of the ecliptic; stars labeled; *naskhī.*

Metal meridian and horizon rings.

Citation

Ashfaque, 222, no. 36.

131.

Location: Present location unknown.

A wooden Sanskrit (Devanāgarī script) celestial globe with stars; has metal stand.

Photographs in the files of Alain Brieux, Paris.

132.

Location: Present location unknown.

A Sanskrit (Devenāgarī script) armillary sphere that has 21 stars indicated on pointers.

Photographs in the files of Alain Brieux, Paris.
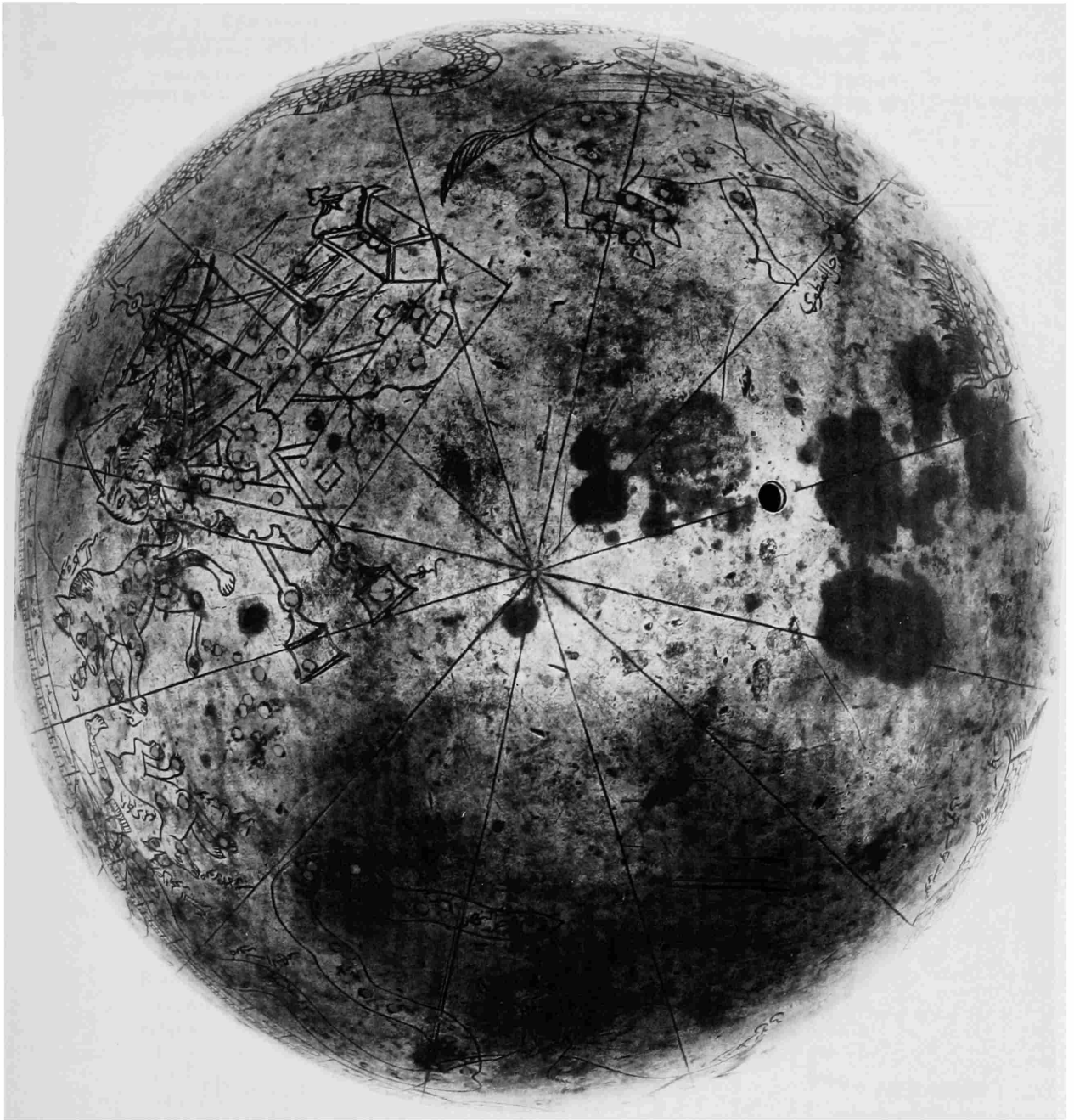
FIGURE 88.—View of the southern ecliptic pole of the Smithsonian globe. (Photo: Smithsonian no. 72-3080)

7. Tables of Basic Characteristics of the Globes

(See pages 213–217 for explanation of Tables. Throughout the Tables globes are referred to by Catalog numbers.)

TABLE 1.—Total number of globes by class

Globe classification	Total	Undated	Dated	Catalog Nos.
Class A				
Constellations with stars	58	25	33	1–58
Constellations only	3	3		55, 56, 58
Class B				
Stars but no constellations	32	15	17	59–90
With zodiacal figures	4	2	2	63, 73, 82, 83
Class C				
No stars or constellations	34	32	2	91–124
Unclassified	2			125, 126

TABLE 2.—Graduations of ecliptic and equator; globes are referred to by Catalog number

Engraved graduations	Class A	Class B	Class C
½° with every fifth line longer	38, 53	none	none
1° with every third line longer	36	none	none
1° with every fifth line longer	1, 2, 4, 5, 6, 7, 8, 9, 11, 12, 13, 17, 18, 20, 22, 23, 24, 27, 28, 29, 30, 31, 34, 35, 40, 41, 44, 55, 58	59, 60, 61, 62,[a] 65, 68, 73, 75, 76,[b] 81	96, 107, 113, 117
1° with every sixth line longer	3, 16, 26, 29, 31, 33, 42, 43, 53,[a] 54	74, 79, 85, 89, 90	108, 109, 112, 114
1° with every tenth line longer	none	none	93, 95,[b] 111[b]
2° intervals	10, 37	none	none
2° with every sixth line longer	none	66, 69, 70, 71, 86, 87, 88	none

TABLE 2.—Continued

Engraved graduations	Class A	Class B	Class C
2° with every tenth line longer	57	64, 67, 72, 77, 80	97, 98, 99, 100, 101, 102, 103, 104
5° intervals	32, 39, 45, 46	none	none
6° intervals	none	78, 84	none
10° intervals	none	none	116
Ungraduated	47, 48, 56	63, 76,[a] 82, 83	91, 92, 94, 95,[a] 105, 110, 111, 115, 118
Unknown	14, 15, 19, 21, 25, 49, 50, 51, 52	none	106, 119, 120, 121, 122, 123, 124, 125, 126
Standard numerals rather than *abjad*	31	75	none
Standard numerals with *abjad*	53	none	93 (on the ring)
Devanāgarī numerals	29, 54	none	none
Equator numbered continuously from vernal equinox	1, 2, 3, 11, 12, 13, 16, 18, 20, 22, 23, 24, 26, 27, 28, 29, 30, 31, 32, 34, 40, 41, 42, 44, 45, 46, 55, 57	61, 62, 65, 67, 73, 74, 75, 77, 79, 80, 81, 84, 86, 89, 90	93, 96, 97, 98, 99, 100, 101, 102, 103, 104, 112, 113, 116
Equator in two 180° segments	38	68, 78, 85, 87	114
Equator in four 90° segments	39, 43	71	none
Equator in 3 segments of 100°, one of 60°	4, 5, 6, 7, 8, 35	59	none
Equator has each 6° segment assigned a number 1 through 60	33, 53 (cf. 54)	none	none
Both equator and ecliptic repeat every 30°	none	60, 88	none
Ecliptic labeled continuously from vernal equinox	11,[c] 38	none	none
No labeling of ecliptic	7, 8, 9	none	none
No labeling of either ecliptic or equator	10	76	none
Solstitial colure graduated	16	74	113

[a] Equator only.
[b] Ecliptic only.
[c] Second set repeats every 30°.

TABLE 3.—Accuracy of globes

Accuracy of engraving	Class A	Class B	Class C
Uniform and accurate graduations	1, 2, 3, 4, 5, 7, 8, 10, 11, 12, 13, 16, 17, 18, 20, 22, 23, 24, 26, 27, 28, 29, 30, 31, 33, 34, 35, 36, 38, 39, 40, 41, 42, 43, 44, 47, 54, 55, 57	59, 64, 65, 66, 67, 68, 69, 70, 71, 72, 74, 75, 76, 77, 78, 79, 80, 81, 84, 85, 86, 88, 89, 90	98, 110, 111, 114,[b] 118
Ungraduated, uniform circles	48	none	91, 92, 94
Technically inaccurate and non-functional	6, 9, 32, 45, 46, 53,[a] 58	60, 61,[a] 62,[a] 63, 73, 82, 83, 87	95, 96, 97, 99, 100, 101, 102, 103, 107, 108, 109, 112, 113, 115,[a] 116
Graduated evenly, circles poor	none	none	104
Ungraduated, circles poor	56	none	105
Unknown	14, 15, 19, 21, 25, 37, 49, 50, 51, 52	none	106, 117, 119, 120, 121, 122, 123, 124, 125, 126

[a] Moderately inaccurate.

[b] Graduations uneven, but circles good.

TABLE 4.—Presence of circles other than ecliptic and celestial equator

Type of circle	Class A	Class B	Class C
Equatorial polar circles	2, 3, 23, 26, 27, 28, 30, 33, 36, 43, 54, 56, 58	60, 63, 64, 66, 67, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89	91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 107, 108, 109, 111, 112, 113, 114, 115, 117
Equatorial tropic circles	16, 22, 23, 26, 27, 29, 33, 36, 43, 53, 56, 57	63, 64, 66, 67, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90	91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 107, 108, 109, 111, 112, 113, 114, 115, 116, 117
Lesser circles at 12° parallel to equator	57	63,[a] 83, 87	none
Lesser circles at 20° parallel to equator	none	none	93, 95[a]
Lesser circles at 12° and 20° parallel to equator	33, 36, 53, 54	70, 72,[b] 90	108, 109, 112, 116
Ecliptic polar circles	2, 16, 30, 36, 43, 56	60, 72, 89	96,[d] 100, 101, 102, 103, 104, 112, 113, 115
Ecliptic tropic circles	none	63, 72, 77, 83	95, 96, 99, 100, 101, 102, 103, 114
Equinoctial colure	16, 31, 43, 56	63, 64, 70, 76, 78, 80, 83, 84, 85, 88, 89	91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 109, 114, 115, 118
Meridians	33, 53, 54	63,[c] 72, 75, 76, 83,[c] 90	93
Lacking ecliptic latitude circles	none	72	none
Solstitial colure labeled	10	63, 79, 80, 81	91
Mayl kullī labeled	29, 57	63, 73, 77, 78, 81, 83	91, 92, 93, 94, 96, 97, 99, 100, 101, 102, 104, 108, 110, 112, 114, 115, 116
Obliquity of ecliptic specified	none	73	94, 100

[a] Also parallel to ecliptic.
[b] Ecliptic and equatorial.
[c] Incomplete.
[d] Plus circles 5° and 10° outside.

TABLE 5.—Additional properties

Property	Class A	Class B	Class C
Lunar mansions	2, 11, 38	59, 60, 65, 74, 76, 84, 85	95[a]
Lacking zodiacal names	32, 46, 47, 48, 56	none	none
Star chart of Ptolemy cited	2, 3	none	none
Star chart of al-Ṣūfī cited	6, 7, 8	62	none
Star chart of Ulugh Bēg cited	14, 31	65	none
Calendrical eras cited other than Hijrah			
Coptic	31	none	none
Era of Flood	31	none	none
Alexandrian Era	7, 31	62, 65	none
Yazdijird	7, 9, 31	62, 65, 74	none
Reign of Akbar	10	none	none
Reign of Jahāngīr	11, 12, 13	none	none
Reign of Shāh Jahān	23, 24	none	none
Malikshāh (Jalālī) Era	31	none	none
Vikrama Era	33	none	none
AD	33	none	none

[a] Named, but no stars indicated.

TABLE 6.—Construction of globes

Material/fabrication	Class A	Class B	Class C
Wood or *papier mâché* covering on wooden core	36, 56	72,[a] 73, 76	93, 94
Hollow metal, no seam visible, and plugs visible	6, 9, 10., 11, 12, 13, 15, 18, 20, 22, 23, 24, 26, 27, 28, 29, 32, 33, 37, 38, 39, 40, 41, 42, 43, 44, 45, 47, 48, 54	60, 66, 67, 68, 69, 70, 71, 74, 84, 85, 86, 87, 88, 89, 90	111, 113, 114, 115, 117
Hollow metal hemispheres	1, 2, 3, 4, 5, 7, 8, 16, 17, 30, 31, 34, 35, 57	59, 61, 62, 63, 64, 65, 75, 77, 78, 79, 80, 81, 82, 83	92, 95, 96, 98, 100, 103, 105, 106, 107, 108, 109, 110, 112
Metal, unknown whether hemispheres or seamless	14, 19, 21, 25, 46, 49, 50, 51, 52, 53, 55, 58	none	91, 97, 99, 101, 102, 104, 116, 118, 119, 120, 121, 122, 123, 124
Unclassified—125, 126			

[a] Possibly painted ivory.

TABLE 7.—Globes with apparently contemporary rings and stand

Engraving of graduations	Class A	Class B	Class C
Graduations of horizon ring			
1° with every fifth line longer	5, 7, 13, 18, 27, 28, 31, 34, 40	62, 76	99,[c]
1° with every sixth line longer	3, 29, 33, 42, 54	none	114
2° with every sixth line longer	32, 45	70, 71, 86	101, 102, 103, 104, 105, 115
2° with every tenth line longer	6, 16	72, 77	none
5° intervals	none	79	none
Line at every 30° interval	none	60	none
Nonconsecutive segments converging at notches for meridian ring	3, 5, 7, 13, 18, 27, 28, 29, 31, 32, 33, 34, 45, 54	62, 70, 71, 72, 77, 79, 84, 86	114
Nonconsecutive segments beginning at notches for meridian ring	42	59, 76	99, 101, 102, 103, 104, 105
Consecutive segments of 90° in clockwise direction	6, 40	none	none
Consecutive segments of 90° in anti-clockwise direction	16	none	none
Notches at East-West points to accommodate a zenith ring	5,[a] 13, 18,[a] 27, 33,[a] 53,[a] 54	70,[a] 71, 79	none
Gnomons on stand	3, 4,[b] 6	none	115
Graduations of meridian ring			
1° with every fifth line longer	18, 31, 40	none	97,[c] 113, 116
1° with every sixth line longer	3, 33, 53, 54	89	92
2° with every sixth line longer	32, 45	86	99, 101, 102, 103, 105, 115
2° with every tenth line longer	none	72, 77	none
Nonconsecutive segments beginning at poles	5, 31, 32, 33, 45, 53, 54	72, 79	94, 97, 99, 101, 102, 103, 105
Nonconsecutive segments converging at poles	6	none	113, 116
Total globes with contemporary rings and stand	3, 5, 6(?), 7, 13, 16, 18, 27, 28, 29, 31, 32, 33, 34, 40, 42, 45, 53, 54	59, 60, 62, 66, 67, 69, 70, 71, 72, 76, 77, 79, 84, 86, 89	92, 94, 95, 97, 99, 101, 102, 103, 104, 105, 108, 113, 114, 115, 116

[a] Ring extant.
[b] Rings and stand not contemporary.
[c] Every fifth degree line longer, but labeled as 6° intervals.

8. Major Inscriptions on the Globes

The Roman numerals in the margins refer to the catalog entry numbers employed in Chapters 6 and 7. The editing conventions are those of the Leiden System applied to the editing of Arabic inscriptions; see Burgoyne & Abul-Hajj, and Dow.

I

صنع هذه الكرة ذات الكرسى لذى الوزارتين القـايد الاعلى ابى عيسى بن لبون
ادام الله عزّه وتأييده عبده ابراهيم بن سعيد السهلى الوزان فى بلنسية
مع محمد ابنه فـوضع الكواكب الثابتة فيها على حسب اعظامها واقطارها فتمّت
فى اوّل صفـر عام تعح لهجرة [النبي] صلّـ<ى> الله عليه وسلم تسليما

II

1 هذه الكرة تشتمل على جميع الكواكب
2 المـذكورة فى كتاب المجسطى بعد تسييرها
3 بحسب المدة التى بين ردد بطلميوس وسنة ثم
4 للهجرة وهو يه درجة و يح دقيقة
5 صنعه يونس بن الحسين الاصطرلابى
6 سنه ثلط

III

1 برسم خزانة مولانا السلطان الملك
2 الكامل العالم العادل ناصر الدنيا
3 والدين محمد بن ابى بكر بن ايـوب عز نصره

1 برسم قيصر بن ابى القـاسم بن مسافـر الاشرفى الحنفى
2 سنه ٦٢٢ هجرية بزياده يو درجة مو دقيقة
3 على ما فى المجسطى

IV

1 صنعه الفـقير الى الله تعالى محمد بن هلال المنجم المـوصلى
2 فى سنة خعد هجرية

V

صنعه محمد بن مويد العرضى

VI

صنعه محمد بن محمود الطبرى

1 رسمت هذه الكواكب من كتاب الصور لابى الحسين الصوفى بعد
2 الزيادة على الطوالها الزمانيا (خطأ ظاهر) ه درجة وتصحيح ما جرى
3 قيه سهوا وتصحيف على المترحمين
4 وذلك فى سنة ٦٨٤ وكتب محمد بن محمود الاصطرلابى

VII

1 رسمت هذه الكواكب من كتاب الصور لابى الحسين
2 عبد الرحمن الصوفى بعد الزياده على الطوالها
3 لرماسا وج فى سنه نسد الهجريه ودلب (ذلب)
4 اليزدجرديه وعحعد (غخعد) الاسكندريه
5 صنعه جعفر بن عمر بن دولتسا
6 الكرمانى

VIII

1 رسمت هذه الكواكب بزياده و[كج] على
2 الصور ابو (خطأ ظاهر) الحسين عبد الرحمن الصوفى
3 فى سنه دفه (ذفه) الهجريه صنعه
4 جعفر بن عمر بن دولتساه
5 الكرمانى

IX

1 هما عمل اضعف [العباد ...] الاعز
2 جمال الدين محمد [بن .... ال]دين محمد
3 الهاشمى نسبا المكى مولدا
4 [..........] فى اشوف بلاد
5 [...... ال]عظيمة زادها
6 [......] كرامة وتعظيما
7 فى سنة ظفا هجرية

8 ٩٨١ وظنب
9 يزدجردية

X

1 المفتقر الى الله الرحمن على كشميرى ابن لقمان سنة ٩٩٨ مولفق ٣٤ اكبرى
2 ثبت على الكرة كواكب المرصودة بعد استخراج تقويمهن وصنعها
3 بنوع يفيد معرفة جميع احكام الاسطرلابين تذكرة للمهره

XI

1 صاحبه نواب اعتقادخان vacat سنه ١٨ جلوس جهانگیری
2 صنعة اقل العباد قايم محمد ابن عيسى ابن الهداد اسطرلابي لاهوري همايوني

XII

سنه ١٠٣٥ هجري vacat صنعة اقل العباد قايم محمد ابن عيسي ابن
الهداد اسطرلابي لاهوري همايوني vacat سنه ٢١ جلوس جهانگیری

XIII

1 صنعة اقل العباد قايم محمد ابن عيسي ابن الهداد اصطرلابى لاهورى همايونى
2 سنه ٢٢ جلوس جهانگیری

XIV

صنعة اقل العباد قايم محمد ابن عيسي ابن الهداد اصطرلابى لاهورى
همايونى سنه ١٠٣٧ هجرى

تمت اين كره مكمل مشتمل بيك هزار وبست ودو كواكب كه جميع از ان چهل
وهشت صورت موصوده نموده اند [-- -] اهل علماء وحكماء تنجيم چنانچه مرصوده
درر صد مزا الغ بیگ است ، وبر تقويم هر كواكب ثابته سه درجه زياده
كرده ايم بحساب حكماء وعلماء اين فن تابابن تاريخ سنه ١٠٤٧ هجرى

XV

1 صنعت اضعف العباد
2 محمد مقيم ابن عيسى ابن
3 الهداد اسطرلابى

4 همایونی

5 لاهوری

6 فی سنه ۱۰٤۹ هجری

XVI

1 صنعه تراب عتبه الوظا

2 محمد زمان ۱۰۵۰

XVII

خاك ره ان محمد زمان ۱۰۵٤

XVIII

1 این صنعت ضیاء الدین محمد

2 ابن قایم محمد ابن عیسی ابن الهداد

3 اسطرلابی همایونی لاهوری

4 فی سنه ۱۰۵۵ هجری

XIX

1 این صنعت ضیاء الدین محمد ابن قایم محمد ابن عیسی

2 ابن الهداد اسطرلابی همایونی لاهوری

3 فی سنه ۱۰۵۷ هجری

XX

1 عمل اقل العباد ضیاء الدین محمد ابن قایم محمد

2 ابن ملا عیسی ابن شیخ الهداد اسطرلابی همایونی

3 لاهوری سنه ۱۰٦۰ هجری

XXI

عمل اقل العباد ضیاء الدین محمد ابن قایم محمد ابن ملا عیسی ابن
شیخ الهداد اصطرلابی همایونی لاهوری فی سنه ۱۰٦٤ هجری

XXII

عمل اقل العباد ضیاء الدین محمد ابن قایم محمد ابس ملا عیسی ابن

شیخ الهداد اسطرلابی همایونی لاهوری فی سنه ۱۰۶۷ هجری

XXIII

عمل اقل العباد ضیاؤ الدین محمد ابن قایم محمد ابن ملا عیسي
ابن شیخ الهداد اسطرلابی همایونی لاهوری فی سنه ۱۰۶۸ هجری
جلوس مبارک ۳۲ جهان شاه

XXIV

عمل اقل العباد [ضـ] ـیاؤ الدین محمد ابن قایم محمد ابن ملا عیسي
ابن شیخ الهداد اسطرلابی همایونی لاهوری فی سنه ۶۸ [۱۰ هجری
جلوس [مبارک ۳۲ جهان شاه

XXV

1 بفرمایش شیخ عبد الخالق
2 عمل محمد صالح تتهوی (کـذا) سنه ۱۰۷۰

XXVI

عمل اقل العباد ضیاؤ الدین محمد ابن {محمد} < قایم > محمد ابن ملا
عیسي ابن شیخ الهداد اسطرلابی همایونی لاهوری فی سنه ۱۰۷۱ هجری

XXVII

عمل اقل العباد ضیاؤ الدین محمد ابن قایم محمد ابن ملا عیسي ابن
شیخ الهداد اسطرلابی همایونی لاهوری فی سنه ۱۰۷٤ هجری

XXVIII

عمل اقل العباد ضیاؤ الدین محمد ابن قایم محمد ابن ملا عیسی ابن
شیخ الهداد اسطرلابی همایونی لاهوری فی سنه ۱۰۷٤ هجری

XXIX

عمل محمد صالح تتوی (کـذا) سنه ۱۰۷٤

XXX

1 در عهد حضرت محی الدین محمد اورنگزیب بهادر عالم گیر
2 این کره اختراعی بفرمایش نواب مستطاب معلی القاب سیادت ونقاب بنناه

3 این کره اختراعی ارضوی (کذا) سمائی عمل اضعف العباد ضیاء
الدین محمد ابن ملا قایم محمد ابن حافظ عیسی ابن
4 شیخ الله داد همایونی
5 فی سنه ۱۰۹۰ هجریه نبویه

XXXI

کمل عمل هذه الکره بما انتقش علیها من الکواکب الثابته وعددها ۱۰۲۲
کوکبا بعد تصحیح اطوالها علی اصول الغبیگ صاحب الرصد الجدید
السمرقندی برسم مولانا حسن افندی روزنامجیٔ مصر سابق الخلوتی الدمرداش
علی ید اضعف العباد واحوجهم الی رحمة ربّه یوم المعاد المعترف بالعجز
والتقصیر رضوان الحقیر وذلك لتاریخ اول یوم من سنه ٤٨٠٣ طوفانیه
وهو یوم تحویل النیر الاعظم الی برج الحمل الکاین یوم الاثنین ۱۱ شوال
سنه ۱۱۱۲ هجریة و ١٤ برمهات سنه ١٤١٧ قبطیه و ۱۰ من ادار سنه
۲۰۱۲ للاسکندر رومیه و ۲۰ ترماه سنه ۱۰۷۰ یزدجردیه واول یوم من
فروردین سنه ٦٢٣ مالکشاهیه وکان الفراغ من اتمامها بعون الله تعالی فی
شهر صفر الخیر سنه ۱۱۱۳ فی الهجرة النبویه وحسبنا الله ونعم الوکیل

(مشرق) سوندیب، سنتره ی ، جزیرة الفضة ، سندون ، جزیر الهند ، البحر المظلم ،
البحرین ، سقطره ، صعده ، قلهات ، شرجه ، بنی هلال ، حضرموت ، مقدوشه ،
الزنج ، سقاله ، مرمره ، صنعا ، بهامه ، عرفات ، الطایفه ، (جنوب) عدن ، زبید ،
بلاد الزیلع ، بنی شعبه ، مدینة القس، عشوة ، الیمن ، مارا ، سبا ، ظفار ،
عراق ، جبل القمر ، بلاد السودان ، مهره ، خاسه ، المهرجان ، مظهر النیل ،
تکرور ، بلاد البربر ، کوکو ، عادیان ، دنقله ، زغاو ، جده ، حبشه ،
القصیر ، (مغرب) مراکش ، فاس، تلمسان ، توان ، تونس، قیروان ، طرابلس
الغرب ، برقه ، اوجله ، اسیوط ، فیوم ، رشید ، دمیاط ، مصر ، محله ،
استانبول ، ادرنه ، عقبه ، مویلح ، طور ، بعلبك ، صیدا ، دمشق الشام ، حما ،
حمص، وجه ، حلب ، ملطیه ، بدر ، شط ، رابغ ، مساجد عایشه المدینة المنوره ،
(شمال) الموصل ، بابل ، شوان ، هیت ، بغداد ، کوفه ، القادسیه ، قزوین ،

بلغار ، خراسان ، عبادان ، البصره ، نيسابور ، كازرون ، بلخ ، بخارا ،
سمرقند ، سابور ، اصفهان ، سد ياجوج ، الهند ، كابل ، هرموز ، هرمز

XXXII

1 بر خْسْبْ (؟ بر خبير ؟) مؤيد جْنْابْ مستطاب اخوند سْيْدْ
2 مظفر اعبيدْ الرحيمْ اتمام يافت تاريخ سنه ۱۲۱⟨۱⟩

XXXIII

1 اين كرهٔ رصدي كه مشتملبر هيئت صوری فلك البروج ودواير
عظيمه عشره كه منجمله آن دايره افق ونصف النهار
2 ودايره سموت ودايره ارتفاع اين هر چهار كه حاوي كره اند ومعدل
النهار ومنطقه البروج ودواير عروض وماره باقطاب
3 اربعه وعديم الميل ودواير ميول اين دواير ششگانه متحرك اند كه بر تن
كره مرتسم ومتنقش بر چهل وهشت تصوير يعني ببست ويك شمالي
4 وپانزده جنوبي وتصاوير دوازده گانه كه بر اوصاع بروج در وسط موجود اند
ويكهزار وبيست ⟨و⟩ دو كوكب مرصوده كه بميخهاي نقره مثبت
ومنجر بر جميع احكام زماني ومكاني وجهاتي
5 كه آنرا احكام ثلثه مى نامند بتجويز حضور فيض گنجور سنگه صاحب
فياض زمان وحيد العصر خاتم الدوران نهال سنگه صاحب بهادر
الهواليه (كذا) كه در جميع علوم على الخصوص در علم رياضي
6 يعنى هيئت وهندسه بي نظير ويگانه آفاق اند باهتمام لاله بلهومل
لاهوری منجم ومهندس وهيئت دان كه يكى از ملازمان سركار سنگه
صاحب موصوف وبانعام ده اشرفي
7 سر تصوير همگى چهارصد وهشتاد اشرفي گلدار مورد عنايات خاصه
گرديد در سمت يكهزار وهشتصد ونود ونه و vacat كرمادت
ومطابق يكهزار ودوصد وپنجاه وهشت
8 هجري وموافق يكهزار وهشت ⟨صد⟩ وچهل ودو عيسوي در دار
الرياست كپورتهله

9 ترتيب يافت

XXXVII

استصنعه واستصوره الفقير الى الله ابو القاسم بن مولانا واستاذنا
علامة زمانه ووحيد اوانه عبد الرحمان بن حسن رحمهما الله رحمه وسعه

XL

1 اسما بلاد : موصل ، الزبير ، مرند ، نخجوان ، مراغه ، تبريز ، كوفه ، بغداد ،
بصره ، عبادان ، فيروزاباد ، شيراز ، يزد ، شهرورر (كذا) ، نهاوند ،
ابهر ، همدان ، نوخ ، قزوين ، اصفهان ، قم ، ري ، استراباد
2 اسما بلاد : مدينه رسول ، مكة معظمة ، هجر بحرين ، بيت المقدس،
مهديه ، قيروان ، طرابلس مغرب ، اندلس، اسكندريه ، مصر ، عدن ، يمن ،
زبيد ، عسقلان ، طبريه ، طرابلس شام ، دمشق ، بعلبك ، حلب

LIX

صنعه بدر بن عبد الله مولى بديع الزمان سنه ثلة

1 من متملكاب (خطأ ظاهر) بديع الملك
2 عماد الدولة بن عماد الدولة بن محمد علي ش.جعلي شاه
3 تغمد رحمه الله بغفرانه فيسنه (كذا) ١٣٠٤

LX

1 عمل عبد الرحمن بن
2 برهان الموصلي فى شهور
3 سنه ثمان عشر وسبعمائه

1 مطوى بر نظر
2 الفقير الحقير
3 غياث المشهور المنصور
4 فى شهور سـ[ـنة ....] عشر وسبعمائه

1 برسم خزانه

2 السلطان المأظ

3 العادل الغ بيك

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1 ∅ اسه٢ الـ ٢* وسه و— ٦ *

LXI

1 صنعه محمد بن جعفر

2 الاصطرلابى فى سنه

3 صمح (ضيج) الهجريه

LXII

1 صنعه محمد بن جعفر

2 بن عمر الاصطرلابى

3 الملقب بحلال

---

1 رسمت هذه الكواكب بعد الزياده

2 الطوالها رة على صور لابى الحسين

3 بن عبد الرحمن الصوفى فى سنه صلد

4 الهجريه وضه اليزدجرديه

5 وعدلح (غذلج) الاسكندريه

LXIII

1 حسب الامر

2 سلطان السلاطين

3 معظم والمقتدر بندهٔ

4 شاه ولايت عباس

5 خاتميافت

6 ١٠١٢

LXIV

صنعه محمد زمان

LXV

1 رسمت هذه الكواكب بعد زياده د اطوالها
2 دامج على موصد السمرقند
3 في سنه غنو الهجريه وغد
4 اليزدجرديه و
5 غظفو (كذا) الاسكندريه

LXVI

1 عمل ضياؤ الدين محمد ابن قايم محمد ابن ملا عيسي
2 ابن ملا الهداد اسطرلابي همايوني لاهوري
3 في سنه ١٠٥٨ هجري

LXVII

1 صنعه اضعف العباد
2 لطف الله ابن
3 عبد القادر
4 المحب اسطرلابي
5 غفر الله
6 ذنو
7 به

LXVIII

1 صنعة قليل العباد حامد ابن محمد مقيم
2 ابن عيسى ابن الهداد اسطرلابي لاهوري همايوني
3 تحرير في التاريخ ٢١
4 شهر شوال
5 سنه ١٠٦٥

LXIX

عمل ضياؤ الدين محمد ابن قايم محمد ابن عيسي ابن الهداد اسطرلابي
همايوني لاهوري في سنه ١٠٧٠

LXX

1 . . ياقت . . . . محمد علی . . . . .

2 فی تاریخ ٤ شهر رمضان

3 المبارك سنه ١٠٨٣

LXXI

1 عمل احقر العباد ضیاء الدین محمد ابن ملا قایم محمد ابن حافظ عیسی ابن

2 شیخ الله داد همایونی

3 سنه ١٠٨٧

LXXII

1 رسمه محمد اشرف

2 توقادی زاده

3 سنه ١٢١٥

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1 عمل محمد اشرف ١٢١٥

LXXIII

1 سبحان اللّه لا اله الا هو فاطر السمٰوات والارضین (خطأ ظاهر) الذی جعل فی السماء بروجا

2 وزیناها للناظرین والشمس والقمر والنجوم مستجرات بأمره الا له (خطأ ظاهر) الخلق والامر تبارك اللّه رب العالمین

3 انّ فی اختلاف اللیل والنهار لایات لاولی الابصار تبارك اللّه احسن الخالقین والشمس تجری لمستقرّ لها ذلك تقدیر العزیز العلیم

4 والقمر قدرناه منازل حتی عاد كالعرجون القدیم ذلك لیعلموا عدد السنین والحساب ان فی ذلك لایات لاولی الألباب

5 تمت علی ید العبد الراجی النادم محمد علی الحسینی الخادم المشرف بخدمة التدریس وعلی مخدومه الف التحیة والثناء

6 بتاریخ یوم السبت ثلث وعشرین من شهر جمادی الاولی سنه ١٢٢١ من هجرة النبویة صلی الله علیه واله

LXXIV

عمل محمد كريم سنه ١١٩٥ يزدجرد شمسى

سنه ١٢٤١ هجري

LXXV

1 دار المعلمين

2 طلبة لوندن كنقرلى

3 حسين حسنينك اختراع

4 ايلد يكى كره سماوى

5 سنه ١٢٩٩ رابيع ٣

XCI

1 بندهٔ مبرا

2 محمد سمئي ترى

3 عمل بر

4 ١٢٣٨

XCII

1 مالكه نواب

2 محمد عليخان صاحب

3 سنه ١٢٤١ هجرى

XCVII

1 لايق مجلس جناب علامه الدوران مجتهد

2 العصر والزمان امام المسلمين حاوى

3 الفروع والاصول جامع العقول وا

4 لمنقول اسوه الفضلاء فخر العلماء ميرزا محمد تقى خطرات دامت بركاته

CXXV

سنه ١٠٤٠ هجرى

Notes

Chapter 1

[1] Neugebauer in *HAMA*, 577 notes that this is perhaps not "natural" and certainly not universal, since the Egyptians perceived the heavens to be a flat roof.

[2] For general discussions of globes in antiquity see Fabricius, second ed., Volume III:455–466; third ed., Volume V:297–306; Thiele, 17–56; Schlachter; and Stevenson, 1:14–23 (very unreliable). See Boll [1903], 88–90, 153–159, for reference to use of globes in astrological literature.

[3] Diog. Laert., II,1. Kirk & Raven, 99 at first interpret this as a celestial globe, citing Suda, who says Anaximander wrote a treatise on a celestial globe (σφαῖρα) but later they (103) reject it as improbable since inconsistent with his cosmogony; see Diels, *Frag.*, I,81. Kahn, 89–90 accepts the idea that Anaximander made a celestial globe, possibly a "solid" type like that attributed to Eudoxus and Aratus or a flat chart of the heavens. See also Gundel & Böker, col. 529.

[4] Cic. *Repub.*, I,xiv. Here he reports the statement of Gaius Sulpicius Gallus through the figure of Lucius Furius Philus who was born about 180 BC.

[5] Cic. *Repub.*, I,xiv; English translation is that of Sabine, Cic. *Repub.* [trns.], 119.

[6] For Eudoxus see Neugebauer *HAMA*, 573, 675–689; Toomer [1], and Huxley *DSB*.

[7] For the life and writings of Aratus, see Knaack; Ludwig; Barber; Tarán; Lesky, 750–752; and Arat. *Phen.* [3], pp. 185–189.

[8] See Walbank; Tarn.

[9] Mair in Arat. *Phen.* [3], pp. 198–201 counts 47 constellations but omits Corona Australis, which is clearly described (lines 400–401); Lamb in Arat. *Phen.* [trns.], 21–29 counts 44 asterisms omitting Hydra, Lupus, Crater, and Corvus.

[10] Arat. *Phen.* [3], p. 210, note e; Arat. *Phen.* [trns.], 87; Hipp. *Comm. arat.*, 25, 28.

[11] Böker, 8–9, 15 *et passim*. See plates 1 and 2 for interesting stereographic projections of the stars in the northern and southern hemispheres as seen on the Aratean globe.

[12] For editions and translations of the poem see, Arat. *Phen.* [1], [2], [3], [4], [5], Arat. *Phen.* [trns.], Martin [1974], and Byvanck.

[13] See Maass [1898] and [1881]; Erren; and Knaack.

[14] For texts see Cic. *Arat.* [1], [2], and [3] (cf. Cic. *Nat. deo.*, II,41–44); for Germanicus see Germ. *Arat.* [1], [2] and [3]; and for Rufus Festus Aviencus see Avien. *Arat.* For the *Aratea* in general see Martin [1956]; Beede; Williams, Maass [1892]; Leuthold; and Kaibel.

[15] The translation was instigated by Ṭāhir ibn al-Ḥusayn, governor of Khurāsān, who lived from AD 775–776 to 822–823/159–207 H; the translation was cited several times by al-Bīrūnī *Astrol.*, 160–161; al-Bīrūnī *India*, 47, 192; al-Bīrūnī *India* [trns.], 1:97, 383. See Honigmann; and Ullmann, 227–228, 309.

[16] Lesky (751); Diels *Frag.*, I,41–42.

[17] Erat. *Catast.* [1] and [2]. See also Lesky, 785–786, Martin [1956], 58; Maass [1883]. Cf. Neugebauer *HAMA*, 287–288; 577–578.

[18] The Augustan poet Manilius, writing during the reigns of Augustus and Tiberius, in his didactic poem *Astronomicon* drew upon both Aratus and pseudo-Eratosthenes, as did the later poet Hyginus in the *Poetica Astronomia*. The latter poem was frequently illustrated. It presented myths associated with constellations and the positions of stars relative to each constellation. See Thiele, 45–56.

[19] Martin [1956], 31–32; cf. Maass [1898], 561–562.

[20] Hipp. *Comm. Arat.*; among other things Hipparchus criticises Aratus for confusing left and right in the descriptions of the constellations, which was very common in all the early descriptions of the constellations, perhaps resulting from the images on a globe being reversed from those as viewed in the sky, and from some people drawing the human constellation figures on a globe so that they face in toward the globe and some drawing them so that they face out from the globe.

[21] Toomer, [2]; Neugebauer *HAMA*, 274–343.

[22] Vogt; see also Neugebauer *HAMA*, 340–341, 277–292; and Pedersen (252 ff); cf. Boll [1901].

[23] Neugebauer *HAMA*, 285–286.

[24] Neugebauer *HAMA*, 292–298.

[25] Schlachter, 14–29; Neugebauer *HAMA*, 931; Vogt; Dijksterhuis, 24.

[26] Ptolemy refers to the configurations of the asterisms (ἀστερισμός) on Hipparchus's "solid globe" (στερεὰ σφαῖρα); Ptol. *Alm.*, Book VII, 1; see Ptol. *Alm.* [1], 2:11–12; Ptol. *Alm.* [2], 2:9, Ptol. *Alm.* [trns. Ger.] 2:11–12; and Ptol. *Alm.* [trns. Eng.], 226.

[27] Strabo *Geogr.*, II,5.10. Cf. Geminus *Elem. astr.*, Book XVI; Geminus *Elem. astr.* [1], 172–173. See also Schlachter, 54–57. Strabo also refers to another globe (σφαῖρα, not clear whether celestial or terrestrial) belonging to a certain Billarus, which was taken as booty from Sinopê in Armenia on the coast of the Black Sea when the city was captured by the Roman commander Lucullus (Lucius Licinius Lucullus ca. 117–56 BC); Strabo *Geogr.*, XII,3.11.

[28] Forbes.

[29] Strabo *Geogr.*, I,3.3; present author's translation. Cf. Strabo *Geogr.*, II,5.5.

[30] Cic. *Repub.*, I,xiv; *Repub.* [trns.], 119–120.

[31] This "globe" by Archimedes is also mentioned in Cic. *Nat. deo.*, II,xxxv and Cic. *Tusc. disp.*, I,xxv.63; by the first century AD Ovid in *Fasti*, VI,269–280; the third- to fourth-century Lucius Caecilius Firmianus Lactantius *Div. inst.*, II,5,

Div. inst. [trns.], 114; the fourth- to fifth-century writer Claudian (*Shorter Poems* LI, no. LXVIII in Platnauer's translation); the fifth century Martianus Capella, Mart. Cap. *Nupt. phil.*, II,212 and VI,583; and the sixth-century Cassiodorus, Cass. *Var.*, I,45. See Dijksterhuis, 23–25; Price [1975], 56–57; and Schlachter, 48–54. Archimedes according to Pappus of Alexandria (VIII,3, who cites the authority of Carpus of Antioch) is also supposed to have written a treatise *On the making of spheres* (περὶ σφαιροποιίας), which may well have described the intricate mechanical sphere or planetarium rather than the simpler "solid" celestial globe. See also Lorch [1980b] 290–291 and see especially Zhitomirskii.

[32] Cic. *Repub.*, I,xiv; English translation is that of Sabine, Cic. *Repub.* [trns.], 119–120.

[33] Cic. *Nat. deo.*, II,xxxiv–xxxv.

[34] See Schlachter, 46–54.

[35] Plato *Tim.*, 40d; after mentioning the movements of the sun, moon, and planets, he says that "to describe all this without the visible models of these same would be labour spent in vain" (translation by Cornford, from Plato *Tim.* [trns.], 135; cf. note 1). Such reference may not necessarily imply a mechanically moved device of the type generally associated with the Archimedean model.

[36] Galen *UP*, XIV,5: "For just as there are those who imitate the revolutions of the wandering stars [the planets] with models which by means of certain instruments they endow with the principle of motion and who go away themselves while the instruments [continue to] act as if their creator were present and always controlling them, so in the same way . . ." (English translation that of May from Galen *UP* [trns.], 2:627).

[37] See Price [1975], 57–58 for a detailed estimate of the gear ratios.

[38] Hultsch; see also Tannery [1893] and Lorch [1980b], 291. For related Chinese devices of the second to eleventh centuries see Lorch [1980b], 291–292 and Needham, Ling, & Price, 44–47.

[39] Price [1975], 58.

[40] See Lorch [1980b] for an edition and translation of this text.

[41] See Dicks; and Neugebauer *HAMA*, 578–589.

[42] Geminus book XVI, *Elem. astr.* [1], 168–169, *Elem. astr.*, [2] 54–55. See also Neugebauer *HAMA*, 581–582; see Schlachter 46–54 for discussion of "ringed" spheres in antiquity.

[43] The angular distances are given not only in the usual 360° (μοῖρα) but in sexigesimal (ἑξηκοστά) divisions as well; cf. Neugebauer *HAMA*, 582.

[44] For a discussion of the obliquity of the ecliptic in antiquity see Gundel & Böker, cols. 539–540; and Mercier.

[45] Neugebauer *HAMA*, 865–866.

[46] Neugebauer *HAMA*, 836–837.

[47] Ptol. *Alm.*, book VII, 5 to VIII, 2. (*Alm.*[1], 2:38–169; [2], 2:32–83; [trns. Ger.], 2:32–64; [trns. Eng.], 234–258). The number 1022 is sometimes given (e.g., Neugebauer *HAMA*, 285, 890) as Ptolemy himself did (*Alm.* book VIII, 1; *Alm.* [1], 2:169), because the three stars of Coma Berenices (ὁ πλόκαμος) while described in the catalog under the unformed stars of Leo, were not included in the subtotal for the zodiacal constellations nor in the total for the entire catalog (see Chapter 5). See Kunitzsch [1974] for Arabic versions of the *Almagest* and in particular the star catalog; Peters & Knobel; Tallgren; Neugebauer *HAMA*, 280–292, 834–838; and Ibn al-Ṣalāḥ for twelfth-century criticisms of the catalog. For the *Almagest* and Ptolemy in general, see van der Waerden; Toomer DSB; and Pedersen.

[48] Neugebauer *HAMA*, 593–594, 600, cf. 32–34. See also Kunitzsch [1974], 150–160.

[49] Ptol. *Alm.*, VII,4 (*Alm.* [1], 2:36). The reign did not begin in AD 137 as frequently stated (e.g., Neugebauer *HAMA*, 890 and Ptol. *Alm.* [trns. Ger.], 1:15,76; 2:31), for Antoninus Pius was adopted by Hadrian and made a colleague in the tribunate on 25 February AD 138 and was made emperor following the death of Hadrian on 2 July AD 138. For Antoninus Pius, who ruled from 10 July AD 138 to 7 March AD 161 see Aurelius.

[50] Ptol. *Alm.* [1], 2;179–185; [2], 2:92–97 (a poor drawing of the precession globe is on the title page of vol. 2); Ptol. *Alm.* [trns. Ger.] 2:72–76; Ptol. *Alm.* [trns. Eng.], 261–263; very inadequate summary in Stevenson 1:20. See also Neugebauer *HAMA*, 890–892 and figs. 79–80 to Part II, where the interpretation of the design is slightly different. Cf. Ptol. *Geogr.*, I,22.23 and VII,6.7 for Ptolemy's comments on terrestrial globes.

[51] Neugebauer *HAMA*, 891 and figure 80A (to Part II) interprets the passage to mean a central *slit* is made along one-half the circumferences; however, the text speaks of lines (ἡ γραμμή) not slits, and slits are in no way required for the design.

[52] Neugebauer *HAMA*, 986 and 1027.

[53] Ptolemy also described an observational armillary sphere to be used to make direct observations of celestial coordinates (Ptol. *Alm.*, V,1; Ptol *Alm.* [1], 1:350–354, Ptol. *Alm.* [trns. Ger.], 1:254–258); cf. *Alm.*, VII, 4. Ptolemy calls such an armillary sphere an "astrolabe" (ἀστρολάβον) even though he was acquainted with what we today term a planispheric astrolabe. Compare Ptol. *Tetra.*, III,2, where ἀστρολάβα ὡροσκοπία may refer to the same instrument or to a planispheric astrolabe (according to Hartner [1939], 2532, note 1). This observational armillary sphere (which has no globe at the center and has sighting devices mounted on the rings) forms a separate class of instruments distinct from celestial globes or *demonstrational* armillary spheres or spherical astrolabes. See Lorch [1975] for later versions of observational armillary spheres related to the torquetum of Jābir ibn Aflaḥ of Seville in the early twelfth century. Compare also Tycho Brahe's sixteenth-century design of the *armillae zodiacales* (Brahe, 52–55).

[54] Ptolemy, as mentioned above, specifies wood for the rings and presumably for the sphere itself, although he does not specifically say so. Wood (ξυλίνη) is specifically mentioned by two later writers, Achilles Tatius, an astronomer

of the third century AD, in his *Introduction to the Phaenomena of Aratus* (Maass [1898], 62) and the seventh- to eighth-century Leontius in his *On the Construction of the Aratean Globe* (Maass [1898], 565).

[55] Perhaps in some way related to the tradition of making celestial globes is a white marble sundial in the form of a globe, 262 mm in diameter, now at the Archeological Museum, Nafplion, Greece. This unique globe was discovered in 1939 by Carl Blegen in the ruins of Prosymna and attributed to the second century BC. The sphere contains three networks of arcs in addition to the horizon and meridian circles and appears to be a uniquely designed sundial. See Gibbs, 27–30, 376–377, and figs. 62–64.

[56] See Price [1975] for study of remains of a geared calendar computer from the first century BC showing the relative movements of the sun and moon, but not the planets.

[57] Now in the Museo Nazionale, Naples. See Passeri; Thiele, 40–42 and plates II–VI; Schlachter, 42–43; Halma [1822]; Wernicke; Panofsky & Saxl, 232; Gundel & Böker, cols. 614–615 no. 5; Wellesz [1964], 84, for reproduction of eighteenth-century drawing; Stevenson, 1: figs. 7 and 8. The best published photographs are in plate 23 of "Astronomy and Astrology" in *Encyc. World Art*, 2.

[58] Schlachter, 42–43; Gundel & Böker, col. 615, no. 6.

[59] Berlin Museum No. 1050A; see Thiele, 42; Gundel & Böker, col. 615 No. 7.

[60] Schlachter, 44, plate I, figure 17; Gundel & Böker, col. 613, no. 2.

[61] Sala dei busti, 341; see Thiele 43; Gundel & Böker, col. 613, no. 1.

[62] See Gundel & Böker, col. 614 nos. 3 and 4, for two additional ones from the end of the second century AD.

[63] Schlachter, 43–44, plate I, figure 1, suggests it is probably a gnostic or mithra-cult monument of the second or third century AD; see also Thiele 43.

[64] Schlachter, 58–105; Thiele, *passim*; Gundel & Böker, cols. 613–620, 648–649, 659–660, nos. 1–28, 126–128, and 160–162. See also Stevenson, I: figure 10, for photograph of a fresco of about AD 50 found at the villa in Boscoreale not far from Pompeii (now at the Metropolitan Museum of Art in New York) showing what is probably a celestial globe (although no stars are indicated) with five parallels (equator, tropics, and "arctic" and "antarctic" circles) but with no ecliptic shown. The depiction is unique among Greco-Roman artifacts in that the globe bears eight or nine meridian circles.

[65] See Schlachter, 61, plate II, figure 49 for drawing (the gem was in a private collection in 1846; present location unknown). Schlachter suggests the astronomer is intended to be Hipparchus, while Halma on the frontispiece of Ptol. *Alm.* [2], 1 reproduced the drawing, claiming the astronomer to be Ptolemy.

[66] For text see Leon. [1], [2], and [3]. See Stevenson, 1:21–23, for very free paraphrase; see also Schlachter, 34–36.

[67] Leon. [2], 561 lines 15–17.

[68] For this commentator upon Aratus who lived probably in the second half of the second century AD, see Gudeman.

[69] Leon. [2], 562, lines 1–15.

[70] Leon. [2], 564, lines 16–18.

[71] In the first century AD the Augustan poet Manilius described in his poem (Manil. *Astron.*, I,xiv,561–707) a similar arrangement where a celestial globe having the five parallels, two colures, and two oblique circles (i.e., the zodiac drawn as three parallel lines and the Milky Way) was set into two moveable circles or rings consisting of the meridian ring marking the vertex and the horizon ring. The arctic and antarctic circles are said to be 36° (6/60) from the poles, which corresponds to the latitude of Rhodes rather than Rome, which has a latitude of 41°53′. Hence the globes he rather inaccurately described were probably imported into Rome.

[72] Ibn al-Ṣalāḥ, 18.

[73] Dresden, Sächsische Landesbibliothek MS Dc 183, folio 13r. See Thiele, 43, fig. 7, and Lehmann, 25, fig. 66, for reproduction of illustrations. A very similar illustration is in a parallel manuscript in St. Gall, Stiftsbibliothek, MS 250 folio 472r. Both manuscripts have been edited by Maass [1898], 154–171, cf. xxxii–xxxvi, who does not reproduce the illustrations. See Gundel & Böker, cols. 684–685, nos. 242–245, for other manuscripts with illustrations of globes.

[74] For classical Chinese construction of celestial globes, the earliest being AD 435, see Needham & Ling, 382–390; and Needham, Ling, & Price, 94–99.

[75] Creswell, 1(2):400. A later date of about AD 723 or 742 has also been suggested; see Maddison & Turner, 135, note 12.

[76] See Creswell, 1(1): plates 74*b*,*c*,*d*, and 76*a*,*b*. For a good color photograph made after the recent cleaning and restoration by a Spanish conservation team, see Baker & Stamford, 23.

[77] See Saxl for analysis from standpoint of art history and Beer for the interpretation of an astronomer. For citations in both classical Islamic literature and Greek writings of other domes and ceilings that were decorated in a similar tradition, see Saxl, 424 note 5, and Lehmann.

[78] Rome, Biblioteca Vaticana, MS Graec. 1087 (fifteenth century) and Vatican MS Graec. 1291 (ninth century). See Saxl, 426–428. In one of the manuscripts (Vatican MS. Graec. 1087) there is a drawing of a celestial globe (no ring or stand) showing the hemisphere about the winter solstice with figures in reverse order as on a globe. The sphere is divided horizontally by five lines representing the equator and tropic and two additional lines half way between the tropic and the poles, with a center vertical line indicating the solstitial colure and a very wide band for the ecliptic.

[79] Such as the globe No. 5 of the present catalog. See Saxl, 428–430.

[80] See Chapter 2 for the purpose and designation of these circles.

[81] Boulogne-sur-Mer, Bibliothèque Municipale MS 188, folio 20r, and London, British Library, MS Harley 647, folio

21v; both are Latin manuscripts, the first of the tenth to eleventh century and the second possibly ninth century. Photographs of the folios are in *Encyc. World Art*, 2: plate 21. See also Zick-Nissen, plates 52 and 53.

[82] Maddison [1966], 8 note 9 and Maddison & Turner, 66. Beer goes to some lengths to try to explain the positions of the constellation figures and the concentric circles on the dome, but unfortunately seems unaware of the planispheric star charts of the type mentioned in note 81 above and consequently does not consider them as a possible source of design. Taking the suggestion of Maddison one step further and conjecturing that the artist's model, which in fact he did not understand very well, was a stereographic projection of a celestial globe, then more details seem accounted for than by any other explanation.

[83] See Gunther *AW*, 82–103, for an English translation of his treatise on the astrolabe.

[84] For the *Pañcasiddhāntikā* XIV,23–26, see Varāhamihira [1889], 80–81 and Varāhamihira [1970], 1:128–129, 2:89.

[85] Kunitzsch [1974], 15–34, cf. 34–82.

[86] Al-Ṣūfī *Ṣuwar*, 5; al-Ḥarrānī has been added to ᶜAlī ibn ᶜĪsà's name by the editors. Ibn al-Nadīm in the *Fihrist*, book VII,2 (Ibn al Nadīm 1:284 and Ibn al-Nadīm [trns.], 671) says ᶜAlī ibn ᶜĪsà was an apprentice to Ibn Khālid al-Marwarrūdhī the astrolabe maker to the caliph al-Maᵓmūn in Baghdād; Ibn al-Nadīm then goes on to list several instrument makers who were in turn apprentices to ᶜAlī ibn ᶜĪsà. He also wrote a treatise on the use of the astrolabe (see ᶜAlī ibn ᶜIsà *Asṭurlāb*).

[87] Ibn al-Nadīm in the *Fihrist*, book VII,2 (Ibn al-Nadīm, 1:284 and Ibn al-Nadīm [trns.], 670–671). See Price [1975] for suggestion that Rhodes may have been the medium through which complicated technical instrument making passed from the Greek world to Ḥarrān.

[88] *Kurāt kathīrah min ᶜamal al-ḥarrāniyīn* (al-Ṣūfī *Ṣuwar*, 143).

[89] Ibn al-Nadīm in the *Fihrist* book VII,2 (Ibn al-Nadīm, 1:285; Ibn al-Nadīm [trns.], 672, note 167).

[90] Ibn al-Ṣalāḥ, 20.

[91] Hartner *DSB*.

[92] Al-Battānī *Op. astr.*, 3:210–214 is Arabic text; 1:139–142 is Latin translation, with notes on 1:319–321.

[93] Al-Battānī *Op. astr.*, 3:210 lines 4–5; 1:139.

[94] This gnomon is not a sighting device, as has sometimes been asserted (e.g., Lorch [1980a] 158 and [1980b] 295), nor does it have two holes through which the light is aligned as is shown in the drawing appended by the editor and translator of the treatise (al-Battānī *Op. astr.*, 1:320). The globe with gnomon as described by al-Battānī could perhaps be considered as an indirect observational instrument in that the latitude is determined by observing the shadow cast on the sphere by the moveable gnomon, but it is, of course, not a direct observational instrument.

[95] For life and writings, see Harvey; Wiedemann [1]; Ibn al-Nadīm, VII, 3 (Ibn al-Nadīm, 1:295; Ibn al-Nadīm[trns.], 695).

[96] Extant in two recensions; see Worrell for partial translation and summary. It is also sometimes referred to as *Kitāb fī ᶜamal bi-l-kurah dhāt al-kursī* (Book on the Use of the Globe Having a Stand). Princeton University, Garrett Collection (Yahuda Section) MS 4901 has the title *Risālah fī al-ᶜamal bi-l-kurah al-falakīyah*. See Schnell for a German translation.

[97] Steinschneider *Europ.*, 1:77.

[98] See Harper.

[99] Narducci, 24.

[100] Alfonso el Sabio, 1:163–208; for a general discussion of the *Libros del saber de astronomia*, see Procter.

[101] *Kitāb al-ᶜamal bi-l-asṭurlāb al-kūrī*; see Harvey; Seemann [1925], 46–49.

[102] Stern *EI*; Brockelmann *GAL*, 1:223, and *Suppl.*, 1:398; Hauber; Kunitzsch *DSB*[2].

[103] Storey, 41.

[104] Oxford, Bodleian MS Marsh 144; Paris, Bibliothèque Nationale, MS arabe 5036, and Istanbul, Ayasofia MS 2595, respectively. See Upton; Wellesz [1959], [1965]; and Winter. An edition has been printed of the Arabic text based on the Oxford and Paris manuscripts in al-Ṣūfī *Ṣuwar*. There are two published versions of Naṣīr al-Dīn al-Ṭūsī's Persian translation (al-Ṣūfī ed. al-Ṭūsī [1] and al-Ṣūfī ed. al-Ṭūsī [2]). For a French translation of the Arabic see al-Ṣūfī *Ṣuwar* [trns.]. For a discussion of the Latin versions see Kunitzsch [1965].

[105] For ᶜ Uṭārid ibn Muḥammad al-Ḥāsib, a ninth-century mathematician and astronomer, see Ibn al-Nadīm 1:278; Ibn al-Nadīm [trns.], 658; and Ullmann, 316. Among other writings he composed treatises on the use of the astrolabe and the use of the armillary sphere (*dhāt al-ḥalaq*).

[106] Al-Ṣūfī *Ṣuwar*, 2–5; al-Ṣūfī *Ṣuwar* [trns.], 29–31.

[107] Al-Ṣūfī *Ṣuwar*, 2; al-Ṣūfī *Ṣuwar* [trns.], 30 (cf. 37).

[108] Al-Ṣūfī *Ṣuwar*, 1–2; al-Ṣūfī *Ṣuwar* [trns.], 29–30.

[109] *Fī tashṭīḥ al-ṣuwar wa tabṭīh al-kuwar* (Suter [1922], 86).

[110] Suter [1922], 81–82; present author's translation.

[111] *Kitāb al-ᶜamal bi-l-kurah al-falakīyah*, extant in Istanbul, Topkapi Sarayi MS 3505, item 1; Brockelmann *GAL*, Suppl. 1:398. He quotes five authorities; Autolycus, Heron, Philon, Theon of Alexandria, and Qusṭā ibn Lūqā (Lorch [1980b], 297). This treatise is possibly quite important and should be studied and published.

[112] Ibn al-Qifṭī, 440. The maker of astrolabes who saw the globe, Ibn al-Sinbadī, is described by Ibn al-Qifṭī as follows: "This man was in Egypt and one of those people of knowledge, learning and experience in the production of astrolabes and celestial globes." According to al-Qifṭī, Ibn al-Sinbadī also saw in the library in Cairo a celestial globe of brass (*nuḥās*) supposedly by Ptolemy and on it was written "this globe was taken from the Amīr Khālid ibn Yazīd ibn Muᶜāwiyah." The latter was an Umayyad prince (died AD

704) with whom legend has associated an interest in alchemy and other scientific and quasi-scientific subjects.

[113] Al-Bīrūnī *Qānūn*, 3:987–1126; al-Bīrūnī *Astrol.*, 157–164; al-Bīrūnī *Chron.* [trns.], 335–365; see also al-Bīrūnī *Qānūn* 3:1139–1157 for lunar mansions. See Boilot; Kennedy *DSB*; and al-Bīrūnī *Catalog*.

[114] London, British Library MS Or. Add. 7697, *Kitāb al-tafhīm li-awāʾil ṣināʿat al-tanjīm*, copied in 685 H/AD 1286 by Ibn al-Ghulām al-Qūniyavī (Ilkhānid style).

[115] The stars for Constellation 48 are there, but the outline is not drawn and the name not inscribed.

[116] Ṣāʿid al-Andalūsī *Ṭabaqāt*, 934–935; Ṣāʿid al-Andalūsī [trns.], 138–139.

[117] The astrolabes are at Madrid, Museo Arqueologico Nacional (dated Shaʿbān 459 H/June-July AD 1067, Gibbs CCA, no. 117, Mayer [1956] 50–51; Oxford, Museum of the History of Science (Shawwāl 460 H/August AD 1068), Gibbs CCA, no. 118, Mayer [1956], 51; Rome, Observatorio Astronomica di Roma (one dated Rajab 463 H/April AD 1071 and a questionable one dated 493 H/AD 1099), Gibbs CCA, nos. 1167 and 123, Mayer [1956], 51–52; Kassel, Staatliche Kunstsammlungen (dated 478 H/AD 1086), Gibbs CCA, no. 121, Mayer [1956], 52. For further details see Brieux & Maddison.

[118] Suter [1900], 117 no. 278.

[119] Chicago, Adler Planetarium (dated 525 H/AD 1130), Gibbs CCA, no. 2557. Another astrolabe bears only the signature of Hibat Allāh ibn al-Ḥusayn al-Baghdādī, although Badr may have assisted since there is much similarity in the signatures; present location of astrolabe (dated 513 H/AD 1119) is unknown, being at one time in a private collection in Munich; Gibbs CCA, no. 3633, where date is given as 518 H/AD 1124–1125. The author wishes to thank Francis Maddison of the Museum of the History of Science, Oxford, for bringing this material to her attention.

[120] Lorch [1980b].

[121] Gottschalk *EI*; and Gottschalk [1958].

[122] On Qayṣar see Sabra [1969], 8; and Destombes [1966], 45–46.

[123] Mayer [1956], 80.

[124] Barrett, xii–xiii; see also Pinder-Wilson BM.

[125] He also wrote a treatise on some of the instruments used at the Marāgha observatory, which does not, however, mention celestial globes (see Seemann [1928]).

[126] See Minorsky; and Sayili, 187–207.

[127] Hartner [1950], esp. reprint, 220–221.

[128] This globe will be fully analyzed in a forthcoming study by Marcel Destombes. See Destombes [1957], 320 no. 7; and Destombes [1958], 307 note 2. For a guide to Ilkhānid metalwork see *EI* [2], 3:1126–1127.

[129] Sayili, 187–188.

[130] At Paris, Destombes Collection (dated 755 H/AD 1354), Gibbs CCA no. 1205; Massachusetts, S.V. Hoffmann Collection (dated 774 H/AD 1372–1373), Gibbs CCA, no. 15, Mayer [1956] 54; Calcutta, Indian Museum (dated 790 H/AD 1388) Gibbs CCA, no. 16; Gunther *AW*, 130, fig. 16; present location unknown (appeared in a Sotheby sale catalog) dated 790 H/AD 1388, Gibbs CCA, no. 2605. A forgery under his name is at the Greenwich National Maritime Museum (dated 757 H/AD 1356); see Mayer [1956], 53; Brieux & Maddison. Both of the globes by Jaʿfar have holes drilled along the solstitial colure on the opposite side of the ecliptic poles from the equatorial poles and the same distance away. The purpose of these holes is unknown.

[131] In Rabat, Musée des Oudâia (dated 796 H/AD 1393–1394), Gibbs CCA, no. 2710; and Copenhagen, Kunstindustrimuseet (estimated date, AD 1426) Gibbs CCA, no. 3595. See Brieux & Maddison for further details.

[132] Storey, 62–72; Barthold; and Sayili, 272–282. See Zenkert; Hookham; and Shcheglov for photographs of the remains of the observatory.

[133] Ulugh Bēg *Zīj*; Ulugh Bēg *Zīj* [trns. Fren.]; and Ulugh Bēg *Zīj* [trns. Eng.]. See also Kary-Niazov.

[134] Al-Kāshī *Letter*, 96; and al-Kāshī [trns.], 196. See also al-Kāshī *Equat.*, 1–7; and Kennedy [1961].

[135] A Hāshimid is a family member of a line of Meccan sharīfs who ruled Mecca almost without interruption from the tenth century to 1924. See Rentz.

[136] See Guimbretière & Hasan.

[137] In 1935 the dated astrolabe was in the library of Nawāb Sir Salar Jung Bahādur in Hyderabad (see Nadvi [1935], 627; and Gibbs CCA, no. 1120). The two undated ones are in the Billmeir Collection, Museum of the History of Science, Oxford; Gibbs CCA nos. 1089 and 2530. See Brieux & Maddison for further details.

[138] European orientalists frequently write the name as Ilāhdād. See Storey, 157 note 3. The spelling with a single *lam* is a common *nastaʿlīq* spelling and is used in all but two signatures of the Lahore workshop. On two globes, however, (Nos. 30 and 71) the name is written as two words with a double *lam*, that is, as Allāh-dād. See also Nadvi [1935] and Nadvi [1937] and Abbott for other possible interpretations of this name as well as further information on some of the products of this family. See also Wiet [1936] and especially Brieux & Maddison for a complete account of the family.

[139] Abbott argues that Humāyūnī means "royal" and the third and fourth generations of the family were official instrument makers to the *successors* of Humāyūn. Nadvi [1937], 537–538 rejects this interpretation, saying that it clearly applies to Allāhdād alone, and in any case never means "royal" in Persian but only "auspicious." Note that one grandson always signed his works as Qāʾim Muḥammad ibn ʿĪsā ibn Allāhdād Asṭurlābī Lāhūrī Humāyūnī, while the other grandson and the great-grandsons signed their names as . . . . ibn ʿĪsā ibn Shaykh Allāhdād Asṭurlābī Humāyūnī Lāhūrī. This change in order does not affect the interpretation of the *nisbah* Humāyūnī, however. On two globes (Nos. 30 and 71) the great-grandson Ḍiyāʾ al-Dīn Muḥammad omits the *nisbah* Lāhūrī from his signature, perhaps indicating that by that time the workshop had

moved to Delhi, the seat at the Mughal court at the time the globes were executed.

[140] For Abū al-Faḍl's *Akbarnāma* I.241, the text is given by Nadvi [1935], 622–623. See Nadvi [1935], 621–626 for other anecdotes regarding Humāyūn's scientific interests, including an account that when Humāyūn reached Tabriz in Persia he ordered his servant to search the city for a celestial globe (*kurah*). The servant interpreted the word for globe as the Persian word for a colt, and so brought before Humāyūn a selection of young horses. It is also reported by Abū al-Faḍl in the *Akbarnāma* that Humāyūn died after falling down the stairs of his library in Delhi which was on the third floor of a building and had been converted into an observatory. Humāyūn was apparently hurrying down for the evening prayer which had interrupted a discussion with a group of mathematicians in the observatory while awaiting the appearance of the planet Venus.

[141] Jahāngīr *Memoirs* [2], 82.

[142] One astrolabe is dated 1009 H/AD 1600 and two are dated 1013 H/AD 1604, the former published in a Sotheby sale catalog (present location unknown), Gibbs CCA, no. 3828, and the latter two at the Adler Planetarium in Chicago and the Palais de l'Orient, Paris, Gibbs CCA nos. 1096 and 1604. Two undated astrolabes are in private collections in London and Chiswick, Gibbs CCA, nos. 68 and 3825.

[143] In Hannover, in the Kestner-Museum, and the Museum of Arab Antiquities, Baghdad, Gibbs CCA, nos. 1609 and 3820, respectively.

[144] See Brieux & Maddison for a complete listing. A partial list includes the following: astrolabes at Delhi, Red Fort Archaeological Museum (dated 1034 H/AD 1624 and 1047 H/AD 1637), Gibbs CCA, nos. 3723 and 3721; Delhi, National Museum (1034 H/AD 1624), Gibbs CCA, no. 2700; Baghdad, Museum of Arab Antiquities (1040 H/AD 1630), Gibbs CCA, no. 3826; Oxford, Museum of the History of Science (1044 H/AD 1634, 1053 H/AD 1643, 1051 H/AD 1641, and one undated one), Gibbs CCA, nos. 71, 72, 2531, and 1013; present location unknown (listed in sale catalog of Sotheby's, dated 1047 H/AD 1637, one undated, and one of estimated date AD 1640), Gibbs CCA, nos. 2601, 3828, and 2609; Karachi, National Museum (1047 H/AD 1637), Gibbs CCA, no. 2704; Calcutta, Indian Museum (1048 H/AD 1638), Gibbs CCA, no. 3730; Greenwich, National Maritime Museum (1051 H/AD 1641) Gibbs CCA, no. 1054; Smithsonian Institution, NMAH (1053 H/AD 1643), Gibbs CCA, no. 86; London, British Museum (1070 H/AD 1654), Gibbs CCA, no. 78. The other undated ones are at Leiden, Rijtsmuseum voor de Geschiedienis det Natuurwetenschappen, Gibbs CCA, no. 1097; the private collection of Dr. Sottas, Gibbs CCA, no. 1119; Paris, Landau Collection, Gibbs CCA, no. 3529; Paris, Destombes collection, Gibbs CCA, no. 3537; New Haven, Connecticut, Yale University, Gibbs CCA, no. 3807; Don Mills, Ontario, Ontario Science Museum, Gibbs CCA, no. 3827; and Salem Mass., Peabody Museum, Gibbs CCA, no. 3655. Two astrolabes though unsigned have with confidence been attributed to him (now at Oxford, Museum of the History of Science, Gibbs CCA, no. 1014, and at Hannover, Kestner-Museum, Gibbs CCA, no. 1098). In the Charliat Collection in Paris there is a forgery dated 1053 H/AD 1643, Gibbs CCA, no. 3504, and in Haifa at the National Maritime Museum there is an undated one generally conceded to be a forgery, Gibbs CCA, no. 3565.

[145] One of the astrolabes is of estimated date AD 1631 and the other dated 1034 H/AD 1624–1625, now at Baghdad, the Museum of Arab Antiquities (Gibbs CCA, no. 3821) and in a private collection in Calcutta as of 1935 (Gibbs CCA, no. 1128), respectively. See Brieux & Maddison.

[146] Jahāngīr *Memoirs* [1], 260, 319; *Memoirs* [2], 81.

[147] *Ibid.* [1], 218, 319–320; *Ibid.* [2], 2, 7, 81, 215, 260.

[148] We do know from written sources of one astrolabe and celestial globe maker who enjoyed the royal favor of Humāyūn (see above, p. 44), while Jahāngīr mentions in his *Memoirs* [2], 98, two mastercraftsmen (*ustādh*) named Pūran and Kalyān "who had no rivals in the art of engraving" and who were requested to make a dagger hilt, and also a European goldsmith (*Memoirs* [2], 80).

[149] An astrolabe dated 1103 H/AD 1691–1692 is in Istanbul, Türk ve Islam Müzesi, while an astrolabe signed by Jamāl al-Dīn and bequeathed in 1094 H/AD 1682–1683 to a mosque as a perpetual *waqf* by ᶜAbd al-Ghafūr ibn Zayn al-Dīn al-Munajjim al-Lārī is in Paris in the private collection of A. Brieux (Gibbs CCA, no. 3519). A third astrolabe dated 1092 H/AD 1681 is attributed to him and is at the Indian Museum of the Royal Asiatic Society (Gibbs CCA, no. 81). See Brieux & Maddison.

[150] The astrolabes are in the Leonard Linton Collection in Point Lookout, New York (dated 1102 H/AD 1690–1691); Harvard University, Collection of Historical Instruments (1038 H/AD 1628–1629), Gibbs CCA, no. 3624; Cambridge, Whipple Museum of the History of Science (estimated date of AD 1628) CCA no. 3563; Paris, Destombes Collection, CCA no. 3538 (1071 H/AD 1660); London, Clockmakers Company Museum (1099 H/AD 1687) CCA no. 1115; and present location unknown (appeared in a sale catalog of Sotheby & Co.) dated 1086 H/AD 1675, CCA no. 3822; and another in the Destombes Collection in Paris. For details see Brieux & Maddison.

[151] Collection of Alain Brieux, Paris. See Brieux & Maddison.

[152] There are three astrolabes at Chicago, Adler Planetarium (dated 1047 H/AD 1637, 1057 H/AD 1747, and 1071 H/AD 1660), Gibbs CCA, nos. 2558, 1095, and 2554; present location unknown (appeared in a sale catalog of Sotheby's) dated 1056 H/AD 1646, 1071 H/AD 1660, and one undated, Gibbs CCA, nos. 2600, 2607, and 3651; Lucknow, library of Nadwat al-ᶜulama (1059 H/AD 1649) Gibbs CCA, no. 1126; Cardiff, National Museum of Wales (1062 H/AD 1651) Gibbs CCA, no. 1107; Oxford Museum of the History of Science, two dated 1069 H/AD 1658, and one dated 1064

H/AD 1653, Gibbs CCA, nos. 1002, 77, and 2533; Aligarth, library of Nawab Sadar Yar Jung Maulana Habiba al-Rahman Khan Sherwani (1064 H/AD 1654 and 1074 H/AD 1680) Gibbs CCA, nos. 1118, 1116; Cairo, Harari Collection (?Museum of Islamic Art) dated 1068 H/AD 1657, Gibbs CCA, no. 3829; Edgertown, Mass., Hoffman Collection (1070 H/AD 1659) Gibbs CCA, no. 87; Cambridge, Mass., Owen Gingerich Collection (1073 H/AD 1662) Gibbs CCA, no. 3809; London, Victoria and Albert Museum (1074 H/AD 1663) Gibbs CCA, no. 1060; Rampur State Library (1074 H/AD 1663) Gibbs CCA, no. 2511; and Patna (Bihar) India, Khuda Bakhsh Oriental Public Library (1074 H/AD 1663) Gibbs CCA, no. 1117; Jaipur Observatory (1067 H/AD 1656, 1085 H/AD 1674, and 1091 H/AD 1680), Gibbs CCA, no. 2702, 2703, and 80; Paris, Landau Collection, two undated, Gibbs CCA, nos. 3524 and 3525; and Paris, Alain Brieux Collection, undated, Gibbs CCA, no. 3517; and Brooklyn, New York, Brooklyn Museum, one undated, Gibbs CCA, no. 3555. See Brieux & Maddison for further details.

[153] See Kurz, plate XI, for an eighteenth-century engraving of an Islamicate demonstrational armillary sphere with a small terrestrial globe at the center, taken from an edition of the *Jihānnumā* printed in Istanbul in 1732.

[154] Kaye [1918], 27–30, 118, and figures 19–22; Gunther *AW*, 212–213. A *zarqalīyah* astrolabe, frequently called by its Latin name *saphaea Azarchelis*, was so named after its inventor Ibn al-Zarqellu, who attempted to redesign the conventional planispheric astrolabe to compensate for the inconvenience of needing a separate plate for each latitude. Al-Zarqellu himself called the astrolabe al-ᶜAbbādīyah in honor of al-Muᶜtamid ibn ᶜAbbād, King of Seville from AD 1068–1091. In the *Libros del saber de astronomia* of Alfonso el Sabio there is a Spanish translation entitled *Libro de la açefecha* of Ibn al-Zarqellu's treatise on this universal astrolabe. See Hartner [1], 316–317; Michel [1947], 93–102; and Gunther *AW*, 256–262.

[155] Nadvi [1935], 626 quotes text from the *ᶜAin al-Akbarī* by Abū al-Faḍl.

[156] Istanbul, Topkapi Sarayi, dated 1006 H/AD 1597 (Gibbs CCA, no. 3707) and Washington, D.C., Smithsonian NMAH, dated 1020 H/AD 1611 (Gibbs CCA, no. 70).

[157] Oxford, Museum of the History of Science, dated 1057 H/AD 1647 (Gibbs CCA, no. 73).

[158] East Indian Company Museum, dated 1076 H/AD 1665 (Gibbs CCA, no. 23); see Morley, 37–39. Another astrolabe giving Muḥammad Ṣāliḥ as maker is dated 1077 H/AD 1666–1667 (Oxford, Museum of the History of Science, Gibbs CCA, no. 2502). A third astrolabe is in the private collection of Edgerton. See Brieux & Maddison for further details.

[159] See, for example, Morley, 37–39; and Gunther *AW*, 139.

[160] See the map accompanying the article "Hind" in *EI* [2], 4:404–454.

[161] The three undated astrolabes are in Paris, a private collection (formerly Leonard Linton Collection, Point Lookout New York, Gibbs CCA, no. 3677); Teheran, the collection of Dr. Jamileh Yeganeh (Gibbs CCA, no. 3700); and Frankfurt, Johann Wolfgang Goethe Universität (Gibbs CCA, no. 3923); while the one dated 1031 H/AD 1621–1622 is in a private collection in London. See Brieux & Maddison.

[162] See Gascoigne, 140, for a color photograph of Jahāngīr's coins.

[163] Jahāngīr *Memoirs*, [2], 6–7.

[164] One astrolabe dated 1071 H/AD 1659 is now at the Mulla Firuz Library in Bombay (Gibbs CCA, no. 1153); one dated 1085 H/AD 1674 has appeared in a sale catalog of Sotheby & Co. (Gibbs CCA, no. 2608); one dated 1088 H/AD 1677 made for Shāh Subḥān Qulī Bahādur Khān is now at Tashkent, the State Museum for the History of Uzbekistan (Gibbs CCA, no. 1154). Undated astrolabes are in Berlin, Staatliche Museum, Gibbs CCA, no. 1155; Paris, Landau Collection, (Gibbs CCA, no. 3530; Washington, D.C., Freer Gallery of Art, Gibbs CCA, no. 3545; and New York, the Metropolitan Museum of Art, Gibbs CCA, no. 3550. See Mayer [1956], 79. There is one astrolabe dated 1125 H/AD 1713 (Gibbs CCA, no. 2603) that appeared in a sale catalog of Sotheby & Co., but is probably an incorrect attribution. See Brieux & Maddison for fuller listings.

[165] At Oxford, Museum of the History of Science, dated 1057 H/AD 1647 (Gibbs CCA, no. 18).

[166] At London (Greenwich), National Maritime Museum, dated 1070 H/AD 1659 (Gibbs CCA, no. 3813).

[167] Chardin, 1:89. The section on astrolabe construction was not included in the first three editions of his journal. Text reproduced by Michel [1941]. This material was brought to my attention by Silvio A. Bedini of the Smithsonian Institution.

[168] See Gingerich *et al.*

[169] An astrolabe was made for the Ottoman Sulṭān Bāyazīd II (AD 1481–1512) by Shukr Allāh Mukhliṣ Shirwānī in 891 H/AD 1486, now in the Harari Collection, Cairo (?Museum of Islamic Art). Three astrolabes signed by Muṣṭafa Ayyūbī are known, in London, the Science Museum (dated 1114 H/AD 1701–1702; Gibbs CCA, no. 1059); in Paris, the Jacques Shumann Collection (dated 1110 H/AD 1698; Gibbs CCA, no. 1218); and an undated one in Paris, the Destombes Collection (Gibbs CCA, no. 3541). These three by Muṣṭafa Ayyūbī the CCA does not consider to be Ottoman, but from the Arabian penninsula; see Brieux & Maddison. There are unsigned and undated probably Ottoman astrolabes in Oxford, Museum of the History of Science (Gibbs CCA, no. 2537); the collection of Dr. Sottas (eighteenth century, Gibbs CCA, no. 1111); and in a present unknown location (listed in a sale catalog of Sotheby & Co.) Gibbs CCA, no. 2606. These few Ottoman astrolabes are considerably simpler in design and decoration than those produced in the same period from other regions; see Brieux & Maddison.

[170] Sayili, 289–302.

[171] Al-Jabartī, 1:74, 114, and 347; Dorn [1865], 33–35.

[172] Sayili, 244; al-Jabartī, 1:99; Dorn [1865], 34–36.

[173] Al-Jabartī, 1:99; Dorn [1865], 33.

[174] Storey, 93–94. See also Kaye [1918]; and Hunter.

[175] Building larger instruments to ensure greater accuracy of observation had a long history in the Islamic East; see Hartner [1977].

[176] The two astrolabes have an estimated date of AD 1724; both are now at the Jaipūr Observatory (Gibbs CCA, nos. 82 and 83).

[177] Kaye [1918], 8–9.

[178] In recent years they have been restored and preserved by the Indian government; see Kaye [1918]. For photographs of the Jaipūr and Delhi observatories see Nasr [1976], plates 66–69.

[179] Griffin, 491–509; and Latif, 319–320.

[180] Lālah Balhūmal made a large astrolabe for the same patron after the patron had been made a Rājah by the British government, for in a lengthy Persian inscription on the instrument in which he hopes for a long reign for Queen Victoria he states that he made it by order of the Rājah Ṣāḥib Nihāl Singh Bahādur Ahluwālīyah [spelled correctly] at Kapūrthalah in AD 1851 and 1907 of the Vikrama era. The present location of this astrolabe is unknown; it was formerly in the collection of Hew Kennedy, Shropshire. A second astrolabe bears a Persian inscription around the edge to the effect that it was designed for the honorable Sir Henry Elliott, K.C.B., Chief Secretary to his Lordship the Governor-General in Kapūrthalah, Ahluwāliyah, by Balhūmal the astronomer of Lahore in that gentleman's employ, AD 1849; see Gunther *AW*, 1:171–173, no. 60. This second astrolabe was acquired in 1982 by the Science Museum, London. Two unsigned astrolabes, both with estimated dates of AD 1850, have also been attributed to Lālah Balhūmal; one is now in the Egestorff Collection, Dublin, and the other in the possession of Alain Brieux, Paris. Information on these astrolabes was generously furnished by Francis Maddison of the Museum of the History of Science, Oxford. See Brieux & Maddison under the entry "Balhūmal Lāhūrī" for yet a fifth astrolabe. For a second celestial globe signed by Balhūmal see globe no. 127.

[181] Eight Sanskrit astrolabes are known to exist, one by ᶜAbd al-Ghadur Moheb made about AD 1670 (London, Collection of Messrs. Malcolm Gardner, Gibbs CCA, no. 1123); two anonymous ones of estimated date about 1670 (see Kaye [1921], Gibbs CCA, no. 94, and no. 93 at the Jaipūr Observatory); one of estimated date AD 1866 (Rockford, Illinois, The Time Museum, Gibbs CCA, no. 2712); and four undated ones (Chicago, Adler Planetarium, Gibbs CCA, no. 2575; the Riva Collection in South America, Gibbs CCA, no. 3921; and two in the A. Michaelis Collection in London, Gibbs CCA, nos. 3913 and 3914).

[182] Howorth, 823–828. The Indian Section of the Victoria and Albert Museum suggests Oudh in northeast India as the place of origin. However, the *nawāb* of Oudh at that time was Ghāzī al-Din Haydar, and ruled from 1814 to 1827; there was never one named Muḥammad ᶜAlī Khān (see Majumdar, 1016). Furthermore, it being made in hemispheres does not suggest an Indian origin.

[183] There is one astrolabe (a wooden one) known by a maker named Muḥammad Karīm, but it is dated 1133 H/AD 1720, so that it is unlikely that it is the same maker; it is now at the Hermitage Museum in Leningrad (Gibbs CCA, no. 1149).

[184] However, Maddison & Turner, 118, note that Alexandrian and Yazdijird eras appear on Lahore astrolabes. Such is not the case with the globes signed by the Lahore family nor on any seamless (?hence Indo-Persian) globe produced after the sixteenth century, only with the exception of the one by Muḥammad Karīm.

[185] Systematically mapped in AD 1750–1752 by Abbé Nicolas Louis de Lacaille (see Warner).

Chapter 2

[1] The precise number of stars on these globes varies because of the difference in the star catalogs used, the occasional inclusion of extra stars such as the "overlooked star" in Ursa Major, and inadvertent omissions on the part of the maker. See section on Classical Greek and Pre-Islamic Sources in Chapter 5.

[2] A great circle is a circle whose diameter is also the diameter of the globe. Thus a tropic circle or polar circle would not be a great circle, but is referred to as a lesser circle.

[3] It is in fact possible to design a celestial globe on which the relative positions of the stars are not reversed from that viewed from earth, as witnessed by the paper model of a celestial sphere (which is actually a truncated icosohedron rather than a sphere) marketed in London under the name *Stardome*. When using this model, which was selected for its artistic design by the Design Center of London, the user must remember that it is not representing a sphere of stars surrounding the earth; he must imagine the convex surface of stars at any given point to be bent back around him in a concave manner. There is no evidence, however, that any such design was conceived of or attempted in either the Greco-Roman or Islamic contexts.

[4] There was also a tradition evident in the late ninth and early tenth centuries of calling a celestial globe "the egg-shaped" (*al-bayḍah*) instrument, for al-Battānī employed this term (see Chapter 1). Furthermore, al-Khwārizmī says in his encyclopedia written in AD 976 that "the celestial globe (*kurah*) is known as one of the instruments of astronomers and with it you learn the nature of the heavens and the constellations of the stars, and it is also called *al-bayḍah* (the egg)" (al-Khwārizmī, 235).

Dunas ibn Tamīm in his introduction to his tenth-century treatise on the armillary sphere refers to the celestial globe as the "egg-shaped" (*al-bayḍah*) instrument (Stern [1956], 375). This was certainly not, however, the most common term for it. Al-Bīrūnī *Qānūn*, 1:54–55, says the term *falak* (sphere) sometimes "refers to the globe (*kurah*), in particular when it is moveable (*mutaḥarrik*); *falak* thus does not apply

to the motionless [globe], and it is called *falak* only on account of its similarity with the whorl of the rotating spindle." See Hartner [2], 762.

[5] See Bion, 176; Holland, 6; and Smart, 40. There is one extant globe that does not have these circles. It is No. 72, made in 1215 H/AD 1800–1801 by Muḥammad Ashrāf Tūqādī Zādah. I have preferred the term ecliptic latitude circles for these circles because of the Arabic name for them, rather than the term ecliptical circles of longitude employed by Hartner [3], 503.

[6] That is, meridians other than the colures. There are 10 known Islamicate globes which have meridians in addition to the colures. All appear to be late eighteenth- or nineteenth-century eastern products. One (No. 72) was made by Muḥammad Ashrāf Tūqādī Zādah in 1215 H/AD 1800–1801; four are all possibly products of the workshop of Lālah Balhūmal Lāhūrī (Nos. 33, 53, 54, and 90, illustrated in Figures 24, 25, and 26); one is an Ottomon Turkish product made in 1299 H/AD 1882 (No. 75); and two are undated (Nos. 76 and 93, the latter illustrated in Figure 27). Globe No. 63 made in Ṣafavid Persia in 1012 H/AD 1603–1604 for Shāh ᶜAbbās I and the similar globe No. 83 both have some meridians, but not complete sets.

[7] *Celestial* latitude and *celestial* longitude ought not to be confused with latitude and longitude, which are equator-oriented coordinates used for measuring terrestrial distances.

[8] On globe No. 30, illustrated in Figure 17, which is actually a cutout sphere by Ḍiyāᵓ al-Dīn Muḥammad of the Lahore workshop, *every* ecliptic latitude circle is labeled. For example, one has the inscription *īn dāᵓirat ᶜarḍī janūbī az awwal burj al-dalw* (this is the southern latitude circle at the first of the House of Aquarius).

[9] There are five exceptions that do not have the zodiacal houses labeled: Nos. 32, 46, 47, 48, and 56.

[10] There is actually one globe, No. 75, an Ottoman Turkish product made in 1299 H/AD 1882, which has the names of the zodiacal houses written with the top of the writing toward the north pole; in this case the names are not written in an elongated fashion so as to fill out the full 30° of each house.

[11] See the section on Lunar Mansions in Chapter 5 for a discussion of lunar mansions and their significance.

[12] The seventeenth-century maker Muḥammad Ṣāliḥ Tatawī prefered the term *quṭb falak al-burūj* (pole of the sphere of the houses) for the ecliptic pole. This term was also occasionally used by Ḍiyāᵓ al-Dīn Muḥammad of the contemporary Lahore workshop (e.g., on No. 30).

[13] While Ptolemy gave a value for the obliquity of the ecliptic of 23°51′20″, various values were taken in the Islamic world varying from 23°51′1″ to 23°30′17″. When describing his celestial globe al-Battānī specified a value of 23°35′, as did al-Khāzinī (see Chapter 1). See Hartner [3], 503–504 for comparative tables of Islamic values; see also Kennedy [1973], 32–53. Since only two globes have graduations smaller than a single degree, and many globes use intervals of two degrees or more, the obliquity of the ecliptic could only be approximated on a globe. Most globes appear to use a value of about 23½° or 24°; one globe (No. 76) has a measurable obliquity of 23½°, and two globes (Nos. 94 and 100) actually have the value of the obliquity written near each solstitial point, in both cases 23½°. Globe No. 73 made by Muḥammad ᶜAlī al-Ḥusaynī in 1221 H/AD 1806, states that the obliquity is "23 degees, 30 minutes, and 17 seconds," although the globe itself is technically non-functional and inaccurate.

[14] Two globes appear to have no holes at the celestial poles, but only at the ecliptic poles: No. 59, made in 535 H/AD 1140–1141 by an apprentice to a well-known astrolabe maker, and No. 9, dated 981 H/AD 1573–1574, which is a poorly executed non-functional globe, suspended at the north ecliptic pole by a cord. There are three globes that have holes drilled at other positions along the solstitial colure whose purpose is unknown; these are Nos. 7 and 8, both by Jaᶜfar ibn ᶜUmar ibn Dawlatshāh al-Kirmānī, and No. 86. In the case of globe No. 44, possibly unfinished, there are no holes at either the equatorial or ecliptic poles but only at points about 25° on the other side of the equinoxes; similarly positioned holes are found on globe No. 45.

[15] There are two known exceptions to this where standard numerals are used instead of *abjad* numerals, both products of the Ottoman empire: No. 31 made in Cairo by Ridwān in 1112 H/AD 1701, and No. 75, made by Ḥusayn Ḥüsnü Kanqarlī in 1299 H/AD 1882. Two globes employ both *abjad* and standard numerals (Nos. 53 and the ring of No. 96). For the *abjad* alphabet system of numerals see Weil & Colin. Numerals in Devanāgarī script are found on Nos. 29 and 54.

[16] These are the diameters of Nos. 37 and 57. The diameter of No. 10, also graduated by 2° intervals, is unfortunately not known. The ungraduated globes vary in size from 147 mm to 68 mm, with a median size of 112 mm.

[17] No. 11 of the catalog also has the ecliptic numbered continuously, but at the same time it has the ecliptic numbered by 30° segments.

[18] For the term *mayl kullī* see Morley, 12 note 2.

[19] See Chapter 2, note 13.

[20] Nos. 89, 99, and 115. See al-Bīrūnī *Astrol.*, 147, for confusion in the use of the term *dāᵓirat al-mayl* for declination circle and for the ecliptic. On celestial globes the expression is never used for the ecliptic. One globe, No. 33, states in its lengthy inscription that it is *ᶜadīm al-mayl*, "lacking the declination [circle]." It must be interpreted in this case as referring to the equinoctial colure, since the ecliptic is present and the equinoctial colure is missing from the globe, which also has a set of six meridian circles that have been shifted 6° westward so that none pass through the equinoxes.

[21] On the relatively few globes that have meridians other than the equinoctial and solstitial colures (see Chapter 2, note 6) the meridians are sometimes labeled *dāᵓirat al-mayl* or *dawāᵓir muyūl*.

[22] Kennedy [1956], 169.

[23] Of Class A globes there are 19 that have one or more rings contemporary with the globe; there are 15 Class B globes and of Class C a possible 15. See the Tables in Chapter 7 for details as to which globes appear to have contemporary rings or stand.

[24] Only one globe of Class A (No. 6 whose authenticity is somewhat questionable) and two of Class C (Nos. 113 and 116) have the order of the numbered segments of the meridian ring beginning at the points alongside the celestial equator and terminating at the poles. These are the only extant globes to have such an ordering.

[25] Nos. 66 and 69 by Ḍiyāʾ al-Dīn Muḥammad have rings with holes, but they could not be examined sufficiently to establish the pattern; No. 27, also by Ḍiyāʾ al-Dīn Muḥammad has holes for six latitude settings, but since the ring is ungraduated (?unfinished) the settings cannot be determined.

[26] See Miquel.

[27] For the localities named on the horizon rings of globes Nos. 31 and 40 see their catalog entries. Globe No. 76, which has 144 place names on the ring, was not available for analysis of the names.

[28] Neugebauer *HAMA*, 934 and Gunther *AW*, 1:180. The Fortunate Islands were thought to be 35° west of Greenwich.

[29] Numbering the meridian ring graduations from the point alongside the equator toward the poles would present the advantage of reading the declination of the star directly from the ring, but would require that the globe be rectified for a given terrestrial latitude by either placing the complement of the latitude (colatitude) at the north point of the horizon ring or by placing the degree corresponding to the latitude at the zenith. The latter arrangement of graduations, though it seems equally convenient, does not appear to be a common pattern.

[30] A somewhat obscure chapter entitled "De saber cuemo se fazen las armillas dell atacyr en la espera, et egualar las casas segund la opinion de Hermes, et cuemo obren con ellas," by an unidentified author "Don Xosse nuestro alfaquin." See Alfonso el Sabio, 1:206. See also Lorch [1980b].

[31] In addition to copies of the Qusṭâ ibn Lūqā treatise (see Worrell and above Chapter 1 note 96), the tract by al-Khāzinī (see Lorch [1980b]), and the treatise on the use of celestial globes by al-Ṣūfī (see Chapter 1, note 111), there are a number of others, such as one entitled *Risālah fī al-kurah dhāt al-kursī* extant in several copies including Princeton, Garrett Collection (Yahuda Section) MS 4967, and Berlin, Arabic MS 5869. It is also of interest to look at some of the western treatises on the use of celestial globes, such as those by Holland, Bion, Hood, and Wright.

[32] Worrell, 286–290. Cf. also Lorch [1980b].

[33] See Hartner [1939], 2552; al-Bīrūnī *Astrol.*, 150. See also Qusṭâ ibn Lūqā, chapters 17–18 (Worrell, 291); cf. the chapter appended to the Spanish translation of Qusṭâ ibn Lūqā (Alfonso el Sabio, 1:206–208).

[34] See Wensink & King.

[35] For examples of small portable gnomons, see Rohr, 114. A simple needle or pin will do, especially with *papier mâché* or wooden globes. See also Lorch [1980a], 157.

[36] Such as the calculations described by Hartner [1939], 2551–2554 and by E.S. Kennedy and M. Destombes in the introduction to al-Ṣūfī *Asṭurlāb*, 13–44.

[37] The *zarqalīyah* astrolabe was designed as a universal planispheric astrolabe usable at any latitude, but it was not that commonly employed. See Chapter 1, note 154.

[38] See Hartner [1939], and North.

[39] For treatises on the use of spherical astrolabes by Qusṭâ ibn Lūqā (the authenticity of this treatise has been questioned), al-Bīrūnī, Abū al-ʿAbbās al-Nayrīzī (died ca AD 922), and Abū ʿAlī al-Ḥasan ibn ʿAlī ʿUmar al-Marrākushī (died AD 1262), see Sédillot [1841] and Seemann [1925]. For a treatise by al-Rūdānī, see Pellat [1975] and Janin. See also Maddison [1962] and Alfonso el Sabio, 2:113–122. For the *shāmilah*, a hemispheric astronomical instrument, see Frank, and Sédillot [1841], 148.

[40] Hartner [1], 727–728.

[41] Maddison [1962], 102 note 6.

[42] Maddison [1962].

[43] Collection of Signor Ernesto Canobbio, Como. The instrument, whose *rete* is missing, was displayed at the exhibition "Science and Technology in Islam" held at the Science Museum, London, as part of the Festival of the World of Islam, April—August, 1976. For a description of it, see Canobbio.

[44] Globes Nos. 7 and 8, both fourteenth-century, have a set of holes drilled on the other side of the ecliptic poles from the celestial poles and at a distance equal to the obliquity of the ecliptic along the solstitial colure. Globe No. 86 has sets of holes about 25° distant along the solstitial colure from the ecliptic poles and from the equatorial pole. The purpose of these holes is unknown.

[45] Tannery, *Hist.*, 53; see also Hartner [1], 727.

[46] From a personal communication he circulated among various people interested in Islamicate astronomical instruments. See also Price [1979].

[47] Neugebauer [1949], 246–247; Diels [1924], 213–219, 246–247, and plate XVII; Maass [1902]; Rehm & Weiss; Drachmann; Neugebauer *HAMA*, 869–970; Price [1975], 59.

[48] Maddison [1962], 103 note 13, mentions the *terrestrial* globes with revolving *rete* found on some European astronomical clocks, where he notes they are not observational instruments and that the *rete* does not fit closely over the globe, which has no horizon line or almucantars.

[49] Eliminating for this discussion Nos. 63, 73, 82, and 83, which represent a separate tradition in globe making.

[50] Seemann [1925], 33–34.

[51] For example, see Welch [1979], 186–187, which illustrates a brass bowl from India of the first half of the seventeenth century. Compare the twelve roundels decorating the unusually thick edge of a thirteenth-century Persian astrolabe with geared calendar movement made by Muḥam-

mad ibn Abī Bakr ibn Muḥammad al-Rāshidī al-Ibarī al-Iṣfahānī in 618 H/AD 1221–1222. This astrolabe is now at Oxford, Museum of the History of Science, Inventory No. IC 5 (see Gunther *AW*, 1: plate XXVI). The zodiacal figures on these roundels are shown with planetary symbols that are absent on the celestial globes. See also the 12 zodiacal figures on a twelfth-century bronze mirror of Mesopotamian origin made for an Urtuqid ruler (Fürst Ottingen-Wallerstein Collection; see Kühnel, 164 fig. 131, and Du Ry, 174 fig. 141), and the zodiacal signs on the border of a bronze mirror inlaid with silver made in Syria about AD 1320 (Topkapi Sarayi Museum; see Du Ry, 149). See also Fehérvári, 73–74, for twelfth- and thirteenth-century zodiacal medallions from Iran. Of interest also are the designs by al-Jazarī for zodiacal signs to be put on a large copper disc for a water clock (see, for example, Atil, 103).

[52] See Gascoigne, 140, for a color plate of the coins issued by Jahāngīr.

[53] See Taddei; and also Warburg, 2:631–639.

[54] See Ettinghausen.

[55] Globes Nos. 55 and 58 also do not fit the basic categories. The former is probably simply an unfinished product of the standard Class A globe which was being made by someone not an instrument maker, that is, the constellation outlines were engraved first and then left unfinished without the stars. The second globe was not examined sufficiently to determine its nature.

[56] There is need for a comprehensive and comparative examination of constellation imagery in Islamicate decorative and scientific illustration in an effort to see how many different traditions there were and where they arose. The study should include all the celestial globes with constellations, those astrolabes which have constellation figures, the numerous illustrated al-Ṣūfī manuscripts, the illustrated treatise by al-Bīrūnī (London, British Library MS Or. Add. 7697), along with the Aratus, Abū Maᶜshar, and al-Qazwīnī illustrations, using Latin and Byzantine sources as well as Islamic ones. An eleventh century Persian astrological handbook of Shahmardān Rāzī with pictorial representations of the constellations has recently come to light in a Cairo manuscript and is now being studied by E.S. Kennedy (see *Project. Med. Isl. Astron.* 24, no. 45); this treatise may also be of importance. See also Zick-Nissen.

[57] Ptol. *Alm.* [1], 2:179–185; see Chapter 1, and Chapter 1 note 50.

[58] This according to Worrell, 287. In the two manuscript copies of this treatise examined by this author (Oxford, Bodleian Library MS Hunt. 584, folio 7a and MS Arab. e. 94, folio 6a), the text does not mention a "stone" but employs the general word sphere (*kurah*). An early fourteenth-century Latin treatise on a celestial globe (*sphera solida*) "compilatus a magistro Johanne de Halebeke Flandrensi experto" describes a wooden sphere, although metal is mentioned as a less satisfactory alternative, which is shaped by turning it on a lathe about one axis and then turning it again about a perpendicular axis (Lorch [1980a], 156).

[59] Alfonso el Sabio, 1:163–169. The author wishes to thank Judy Erickson von Gunten for preparing an English translation of the Spanish text.

[60] *Ceni* may perhaps be *qānīᵓ*, meaning dark red, or perhaps *sīnī*, "chinese" as suggested by Seemann [1925], 52.

[61] Alfonso el Sabio, 2:125–216; Seemann [1925], 56–57 presents a German translation and reproduces diagrams from the Spanish text.

[62] Compare the late twelfth-century Islamicate techniques for casting by closed mold boxes with green sand as the casting medium, and casting by the *cire perdue* process described by al-Jazarī in his treatise on mechanical devices written in AD 1206 (al-Jazarī, 191–195, 267–268, and 276; Wiedemann & Hauser, 230–237).

[63] Alfonso el Sabio, 2:118–120; Seemann [1925], 55–56 gives a German translation with diagrams.

[64] As early as the first century BC there is a reference in the *Geography* by Strabo to a sphere being shaped on a turning-lathe (see Chapter 1, note 29). See also Cave.

[65] The thirteenth-century astronomer al-Marrākushī compares the procedure for drawing the circles on a spherical astrolabe where the maker begins with the horizon and meridian to the apparently usual practice of beginning a celestial globe with the solstitial colure and celestial equator (Sédillot [1841], 142).

[66] Alfonso el Sabio, 2:118–124; Seemann [1925], 54 and fig. 12.

[67] Lorch [1980b], 296–297; omitted by Sédillot in his edition of al-Marrākushī.

[68] The traveler Chardin detailed the equipment used in Ṣafavid Persia for making the remarkably steady and precise circles and lines on a planispheric astrolabe, but the techniques do not seem to be applicable to a celestial globe. See Chapter 1, note 167.

[69] As described in the chapter appended to *Librio del alcora*, Alfonso el Sabio, 1:206–208.

[70] Lorch [1980b], 297.

[71] Kennedy [1956], and Ibn al-Ṣalāḥ.

[72] See Mercier.

[73] The epoch of al-Ṣūfī was taken to be 364 H/AD 974. See Hartner [1939], 311 of the reprint, where an addition has been made to the original article.

[74] For the problems involved in dating an instrument on the basis of the position of the vernal equinox and position of stars see Poulle (1956], and Michel [1947]. See G.R. Kaye [1921], 16–19 for an analysis of the star positions on globe No. 71 made by Ḍiyāᵓ al-Dīn Muḥammad in 1087 H/AD 1676–1677; see also Destombes [1957].

[75] Al-Battānī *Op. astr.*, 3:210–214, Arabic text; Latin translation in 1:139–142.

[76] *Ibid.*, 3:213.

[77] Sédillot [1841], 110–115 and plates 4 and 5.

[78] In contrast to al-Marrākushī's theoretical sophistication but practical inexperience is the design for an instrument to measure the central point of three points of unknown position on the surface of a sphere, by the author of the *Book of*

Knowledge of Ingenious Mechnical Devices, Ibn al-Razzāz al-Jazarī. This late twelfth-century writer demonstrates enormous acquaintance with metallurgical techniques but quite rudimentary knowledge of mathematics and, curiously, no interest in the problems and methods of producing spheres (al-Jazarī, 196–198, 268–274).

[79] See Allan, 52.

[80] For example, Nos. 18, 28, 32, 62, 65, 77, 85, 86, 89, 100, and 115.

[81] See, for example, Mukherjee, 167–176 *et passim.*

[82] *Ibid.*, 204–210; and Allan, 38–39.

[83] Smith, 124–128; and Hodges, 73–76.

[84] In a communication from the Assistant Keeper of the Department of Technology, the Royal Scottish Museum, Edinburgh, dated 27 June 1972, Mr. G.W. Anderson suggested after consultation with a silversmith that globe No. 27 of the present catalog must have been raised, adding that the thin cross-section is a strong argument against casting "quite apart from the almost impossible technical feat of casting a seamless globe." In November of the same year, however, he reported that after examining the inside of the globe with a tiny electric lightbulb he concluded that the rough and pitted interior surface and protruding small brass stumps were overwhelming evidence that it had been cast rather than raised.

[85] Only the seamless globes Nos. 9, 27, 28, 38, 42, 48, 60, 86, and 88 have been inspected.

[86] Hodges 70–73; and Mukherjee, 213–225, 230–240. Compare the chapters on seventeenth-century Chinese casting by the lost-wax method in the treatise by Ying-Hsing, 159–170. See also Smith 105–115.

[87] The analysis was carried out by Maurice Salmon then with the Laboratory, but for reasons beyond my control the results have yet to be published. As a result I must simply summarize in very general terms some of the results.

[88] Allan, 52 *et passim.*

[89] See Steinberg, 103–138.

[90] A preliminary attempt was made to compare volume and weight of some of the globes to see if a clear cut pattern emerged when compared with construction methods. Unfortunately, while weight was available for 33 of the metal globes, the wall thickness was known for only 5 globes, one of which was a globe whose weight was unknown. The four globes for which both weight and wall thickness were known were: No. 38, with the thickness varying from .47 mm to 1 mm; No. 9, with a wall thickness of 2.5 mm; No. 41, with a thickness of the shell of 2 mm; and No. 48 whose wall thickness is 0.43 mm. For these four globes, all of which are known to be seamless, the resulting densities are 20.12 (taking a figure of 1 mm for No. 38), 11.35, 4.81, and 33.75, respectively. The resulting densities or specific gravities of the alloys for these four globes cover such a large range of values as to be quite inconclusive. This may be due to the fact that the walls of many globes seem not to be uniform in thickness and frequently incorporate thick plugs, and the fact that for the last globe (No. 48) the weight included that of the metal axis rod. That of globe No. 9 is so low (4.81) as to make one question the reliability of the measurements. Thus no conclusive results can be drawn from these four sets of measurements concerning the densities of alloys in metal seamless globes. When the weight and diameter of the other 29 globes are compared, taking an arbitrary value of 1 mm for the average shell thickness, the results are slightly more suggestive for a density in the range of 11.2 to 22.7 appears to be the rule for nearly all the seamless items. The exceptions to this are globes No. 87 and No. 111, which are known to have very thick walls, although no exact measurement has been taken. Globes known to be in hemispheres range in density from 5.4 to 24.1. One might conjecture that those globes showing a lower density in the range of 5.4 to 9.1 were made by raised hemispheres, while those in the higher values of 11 to 24 are of cast halves. Since, however, the shell thickness varies from globe to globe and even within one globe, it is not possible to draw any definite conclusions concerning the densities of the alloys employed in the globes until many more measurements are available for comparison.

[91] Mukherjee, 213–241 *et passim.* Unfortunately this survey did not include modern Pakistan where Lahore, the seat of the most productive workshops through the nineteenth century, is located.

[92] *Ibid.*, 230–240, 265.

[93] Al-Jazarī, 191–195, 267–268, and 274.

[94] Mukherjee, 357.

[95] See, for example, Allan, 19; and Mukherjee 433.

Chapter 3

[1] The designation of lunar mansions along the ecliptic is not a frequently encountered feature of celestial globes and is not known to occur on any other certain products of the Lahore workshop other than No. 11 and the Smithsonian globe (No. 38). On all the globes where lunar mansions are indicated along the ecliptic (e.g., Nos. 2, 59, 60, 74, 76, 84, and 85) the order begins with the first lunar mansion at the vernal equinox, with only the two exceptions of Nos. 11 and 38.

Chapter 4

[1] I would like to thank Emilie Savage-Smith for encouraging me to undertake an examination of the Smithsonian globe in the spirit of cooperative scholarship. I am grateful to Hanns-Peter Schmidt, Martin J. Powers, and Estelle Whelan for criticism and advice.

[2] See, for example, Wellesz [1965], plate 3.

[3] Al-Ṣūfī *Ṣuwar*, 195.

[4] Although as a rule Cepheus appears as a beared male both on globes and in the al-Ṣūfī manuscripts, Centaurus is sometimes shown beardless, as in Oxford Bodleian MS Marsh 144 (see Wellesz [1965], plate 21).

[5] For lithographs of the figures illustrating the latter two manuscripts, see al-Ṣūfī *Ṣuwar* [trns.], plates I–VI.

[6] For lithographs of the constellation figures on globe No. 5, see Drechsler, plates I–IV.

[7] Wellesz [1964], figure 2.

[8] The Gemini appear as clothed figures in the al-Ṣūfī manuscript in the Metropolitan Museum of Art, New York (Upton, fig. 33), on the Malcolm globe (No. 4) where the twins appear to wear knee-length leggings (Pinder-Wilson *BM*, fig. 146), and in an unpublished al-Ṣūfī manuscript in the Freer Gallery of Art, Smithsonian Institution, Washington, D.C. (MS No. 07-626, folios 53b and 54a).

[9] This device appears only once on the Smithsonian globe, and resembles the rendition of shoulder joints on figures such as Centaurus, Andromeda, and Hercules on globe No. 1, dated 473 H/AD 1080. For a lithograph of the figures on globe No. 1, see Meucci, plate I.

[10] See Chapter 4, note 6.

[11] For lithographs of globe No. 26, see Klüber.

[12] Al-Ṣūfī *Ṣuwar* [trns.], plate V, figure 13.

[13] This sort of necklet also appears to be in evidence on globe No. 26 and in Oxford Bodleian MS Marsh 144; for an illustration of the Andromeda figures in the Oxford manuscript see Wellesz [1965], figures 12–13.

[14] Perseus' winged footgear, as well as a cap of darkness and a wallet, were given to him by the Hyperborean nymphs, and appear as his standard attributes as early as the fifth century BC (see Avery, 854).

[15] In Greek mythology, Boötes was "supposed to represent a man holding a crook and driving the Bear (Ursa Major)" (Avery, 221). This identification does not account for his winged footgear on the Smithsonian globe, which may simply reproduce the type of footgear worn by Perseus by a sort of visual analogy.

[16] Cepheus's boots appear to be part of the costume that identified him as an Ethiopian king, the father of Andromeda and husband of Cassiopeia.

[17] The adaptation or transformation of attributes such as these individualized forms of headgear from pre-Islamic times via copies of the al-Ṣūfī treatise into later Islamic art promises to be a rich field for future study. Such obviously Muslim modifications as Auriga's turban become standard and are repeated, while the headgear of figures such as Cepheus show a much broader range of adjustments.

[18] The easy identification of these beasts depends in large part on the rendition of salient characteristics of their heads, paws, and tails. Once again, certain features, such as the length and width of Ursa's tail, show greater variation than others, a factor that might have been due to artisans's direct observation (or lack thereof) of certain animal types in nature or in captivity.

[19] An alternate practice was followed on at least two of the globes (Nos. 4 and 5), where the fur of animals was indicated by overall patterns of hatching arranged in rows. See, for example, Pinder-Wilson *BM*, especially figure 136.

[20] For a comparable Draco in Oxford Bodleian MS Marsh 144, see Wellesz [1959], figure 20. The head of the Draco figure on the Smithsonian globe is similar to that of the constellation as illustrated in an al-Ṣūfī manuscript in Paris (see Blochet, plate LXXXVIII). The same type of head was used for Serpens in the same manuscript (Blochet, plate XCI).

[21] Globes No. 12 and No. 14 are also signed by Qā᾿im Muḥammad, but photographs are unavailable for study or too poor to permit analysis. The brother of Qā᾿im Muḥammad, Muḥammad Muqīm, also made a globe with constellation figures (No. 15), but this was also unavailable for study.

[22] Globes Nos. 19, 21, and 24 signed by Ḍiyā᾿ al-Dīn Muḥammad were also unavailable for study or the available photographs were not detailed enough to allow comparison.

[23] The Paris al-Ṣūfī manuscript mentioned above (chapter 4, note 20) shows Auriga in the same posture as on the Smithsonian globe; see Blochet, plate XC.

[24] Al-Ṣūfī *Ṣuwar*, 93.

[25] On the Malcolm globe (No. 4), for example, the attribute more closely resembles a horse whip than it does on the Smithsonian globe; see Pinder-Wilson *BM*, fig. 141.

[26] See, for example, Blochet, plate XC; Martin [1912], 2, plate 35; and the unpublished Freer al-Ṣūfī MS (see chapter 4, note 8), folios 19b and 20a.

[27] This attribute can be seen, for example, in Oxford Bodleian MS Marsh 144 (see Wellesz [1959], fig. 8), and on the Malcolm globe, No. 4 (see Pinder-Wilson *BM*, fig. 141).

[28] Al-Ṣūfī *Ṣuwar*, 93.

[29] The facial type and clothing of this figure mark it as coming from a Mughal milieu in a fashion more immediately obvious than is the case with any of the figures on Qā᾿im Muḥammad's globes. This interest in details of contemporary dress and close kinship with contemporary painting styles are identifying characteristics of Ḍiyā᾿ al-Dīn Muḥammad's *oeuvre*.

[30] An example of an even more radical anatomical transformation on one of Ḍiyā᾿ al-Dīn's globes occurs on No. 22, where Capricorn is rendered as a reindeer-like creature.

[31] A remark should be added here concerning the significance of signatures on celestial globes and other metalwork. We still do not know, in the vast majority of cases, the professional identity of the individuals who signed objects, although it is usually assumed, as here, that they were overseers (possibly master craftsmen) who took ultimate responsibility for the quality of a product that was in fact produced by a group.

[32] The term "inverted" refers to the drawing of the ears within the circumference of the head instead of protruding outside of it.

[33] In affirming the femininity of this figure by articulating her anatomy, the maker of the Smithsonian globe joined a small group of artisans who departed from the usual practice of differentiating between male and female figures by means of hairstyles and attributes only. The maker of the Malcolm globe, No. 4, represented Andromeda as bare-breasted with a calf-length skirt (see Pinder-Wilson *BM*, figs. 140, 144);

both Andromeda and Virgo are distinguished by hairstyle, attributes, and feminine costume only in Oxford Bodleian MS Marsh 144 (see Wellesz [1964], figs. 4, 5, and 8).

[34] This hairstyle may be a more elaborate variation of Orion's scalloped coiffure or headdress on the Smithsonian globe.

[35] Ḍiyāʾ al-Dīn's Virgo, with her sinuous, slender figure, jewelry, and more elaborate sash, is dressed more like a court lady or dancing girl than like an angelic figure. Her garments and attitude may perhaps be related to representations of court women in Rajput painting; see, for example, a painting dating from about AD 1660, which shows Prince Murad Baksh receiving a lady at night (Archer, plate 46).

[36] The anatomically correct representation of feline hindquarters posed a problem for Islamic artists in various media. To cite one example, a group of leonine incense burners in bronze from twelfth- to thirteenth-century Persia exhibit a range of leg proportions and postures that indicate some difficulty in coming to grips with the proper placement of knee and ankle joints (see Aran).

[37] Wellesz [1959], fig. 33; Martin [1912], 2, plate 38.

[38] For an example, see an illustration from the sixteenth-century copy of a manuscript attributed to a certain Muhammad al-Sooudi (Blochet, plate CLXXIV).

[39] See Chapter 4, note 18.

[40] See Upton, fig. 34; and al-Ṣūfī *Ṣuwar* [trns.], plate II, figure 26, respectively.

[41] There is also a large vase-like form at the side or center of the vessel, the identity and function of which is unclear.

[42] These bracket-like forms resemble cartouche motifs used widely in Islamic leatherwork, in particular on book bindings. See, for example, Kühnel, figs. 41 and 44.

[43] See Pinder-Wilson *BM*, fig. 155; and Wellesz [1965], fig. 20.

[44] See text for Figure 81 (Argo Navis).

[45] Upton, fig. 48; al-Ṣūfī *Ṣuwar* [trns], plate IV, fig. 40, respectively.

[46] See text for Figure 81 (Argo Navis).

[47] An exception is globe No. 1, where all the human figures are naked except for Andromeda.

[48] On variants of headgear, see Chapter 4, note 17 above.

[49] Generally, shorter (knee-length) tunics appear to have been worn by common laborers, farmers, hunters, or lowly attendants—i.e., men whose professions demanded the greatest freedom of movement. Calf-length tunics, on the other hand, appear as the typical dress of princes and their courtiers in Mughal painting. An interesting example of the juxtaposition of these costume types occurs in the marginal illustrations on a page from an imperial album of Jahāngīr dated ca. AD 1605; see Beach, 49, 51, folio 7v.

[50] See Welch [1978], plate 17 (a miniature from a dispersed copy of the *Jahāngīr-nāma* showing *Jahāngīr in Darbar* and dated ca. AD 1620).

[51] See Beach, 60–61, no. 13 (*Jahāngīr Entertaining Sheikhs* from a *Jahāngīr-nāma* dated ca. AD 1615–1620).

[52] See Welch [1978], plates 18 (a miniature from a dispersed copy of the *Tuzuk-i-Jahāngīri*, ca. AD 1615) and 21 (an album painting entitled *Jahāngīr's Dream*, ca. AD 1618–1622, which shows Jahāngīr himself embracing Shāh ʿAbbās Ṣafavi of Persia).

[53] The earliest of these works, dated AD 1583, is a page from a copy of the *Kitāb-i-Saʿat*, an astrological treatise written at Hajipur. The particular miniature in question, folio 24v, illustrates Mars in Aries; the figure of Mars, dressed in a short tunic with single-looped sash, and carrying a sword over his right shoulder and a human head in his left hand, advances resolutely toward the right. His somewhat squat body bears an uncanny similarity to several of the male figures on the Smithsonian globe. On this manuscript, see Falk, Smart, & Skelton, 19–23, especially page 21. For examples of later paintings depicting male figures wearing tunics and single-looped sashes, see *Ibid.*, p. 80; Beach [1978], 37, no. 1 (folio 41r); 50, no. 7; and 158, no. 56; and Welch [1973], 11, no. 76, and 103, no. 62.

Chapter 5

[1] Tibbetts [1965], [1971]; Kunitzsch [1967], [1977].

[2] Kennedy [1956]; al-Bīrūnī *Qānūn*, 3:987–1126.

[3] Ptol. *Alm.* [1], 2:167–68.

[4] Ptol. *Alm.* [trns. Ger.], 2:48, 66, 67; Baily; Peters & Knobel.

[5] Al-Ṣūfī *Ṣuwar*, 199.

[6] Ulugh Bēg *Zij* [trns. Eng.]; Peters; Baily.

[7] Ulugh Bēg *Zij* [trns. Eng.], 8–9.

[8] Al-Ṣūfī *Ṣuwar*, 94.

[9] Ulugh Bēg *Zij* [trns. Eng.], 10; for comparisons of catalogs see Knobel [1875]; Moesgaard; Peters: Tallgren.

[10] Al-Kāshī *Letter*, 96.

[11] Gundel & Böker, cols. 522–528; Hartner [3]; Hommel; *Encyc. World Art*, 2:34–55 and plate 20 ("astronomy and astrology"); see also Brown; and Gleadow.

[12] Kuntizsch [1961], 22.

[13] See Ideler 214–218; and Kunitzsch [1961], 24, for various interpretations.

[14] Kunitzsch [1961], no. 166b; al-Bīrūnī *Astrol.*, 163; al-Ṣūfī *Ṣuwar*, 289.

[15] Wissmann, 880–881.

[16] This latter image is actually illustrated in two extant manuscript copies of al-Ṣūfī's treatise (Wellesz [1964], 91).

[17] Wiedemann [1926].

[18] Benhamouda; Hartner [3]; Ideler; Mesnard; Samaha; Jurdak; Knobel [1897]; Eilers. See also the general works of Allen; Higgins. For bibliography see Kunitzsch [1959], 3–9.

[19] Al-Ṣūfī *Ṣuwar* (all references to al-Ṣūfī in the following two sections are to the Hyderabad edition); al-Bīrūnī *Astrol.*, 157–164; al-Qazwīnī; see also Ideler.

[20] Neugebauer *OCD*; Buttmann; Boll-Gundel; Aujac; Labordus; Aurigema; Gundel; Schadewaldt; Ramsey & Wilkins.

[21] Kunitzsch [1961] and [1974].

[22] Whitney; Chu.

[23] Yampolsky.

[24] Hommel; Kunitzsch [1959], 53.

[25] Weinstock; Mercier, 42.

[26] Wissmann, 873, 880–881.

[27] The cosmical setting of a star or asterism and the heliacal rising of the opposite star-group, in the ordering of the 28 lunar mansions, marked the beginning of a period called *nawʾ*, hence the term *anwāʾ* used for this early system. The term *anwāʾ* is also used generally for all pre-Islamic terminology, conceptions, and significances applied to star groups by the early Bedouins. See Pellat *EI*, and Pellat [1955]. In much of the literature on lunar mansions and the *anwāʾ* system, a confusion in the use of the term acronychal has occurred. The cosmical setting of a star or asterism in the west as the sun rises in the east has frequently, but incorrectly, been called the acronychal setting. The heliacal rising, sometimes called cosmical, occurs in the east at sunrise.

[28] Al-Bīrūnī *Chron.* [trns.], 335 and al-Bīrūnī *Astrol.*, 164, says the Hindus had 27 divisions; see also Gundel & Böker, cols. 511–514; cf. Kaye [1924], 22–23. Others such as Whitney; Yampolsky; Hommel; and Mercier, all give 28.

[29] Al-Bīrūnī *Chron.* [trns.], 335–336.

[30] Kunitzsch *DSB*. Ibn Qutaybah is quoted extensively in Kunitzsch [1961].

[31] See Pellat [1955].

[32] See, for example, the calendar written in AD 961 (see *Calendrier de Cordoue*) and the thirteenth-century one by Ibn al-Bannāʾ.

[33] Sabra *DSB*.

[34] Al-Bīrūnī *Chron.* [trns.], 338 (translation of Sachau; words in brackets added).

[35] As seen, for example, in the treatises of the thirteenth-century authority on the occult, al-Būnī (see al-Būnī, 18–24). See Savage-Smith & Smith, 39–42, especially the chart on pages 40–41, for a detailed discussion of these patterns.

[36] For further discussion of lunar mansions see especially Kunitzsch [1961] 13–20 *et passim*; Gundel & Böker, cols. 511–519; Steinschneider [1864]; Hommel; al-Bīrūnī *Astrol.*, 164, *Chron.* [trns.], 343–353, *Qānūn*, 3:1139–1157; al-Ṣūfī *Ṣuwar*, passim; al-Qazwīnī, 1:42–54; see also Ideler. See also al-Būnī, 10–25; Ruska; Griffini; Musil. For a brief discussion of the numerical symbolism associated with the lunar mansions (e.g., their sum is equal to the sum of all the integers of the number of planets, 7 + 6 + 5 . . . + 1 = 28) see Nasr [1965], 162–163.

[37] Al-Bīrūnī *Chron.* [trns.], 353–354; see also Savage-Smith & Smith, 40–41.

[38] One might expect *qīfāʾūs*; however, al-Ṣūfī reads *qīqāʾūs*, as do all globes that have diacritical points, except for No. 4, which reads *qīfāʾūs*. The two earliest globes, No. 1 and 34, as well as the later No. 31, bear the title *al-multahib* (the angry one), which al-Ṣūfī also uses, as well as *qīqāʾūs*. (See Kunitzsch [1974], 173–174, for a discussion of the versions of Cepheus's name in Arabic.)

[39] It is of interest that in the diagrams illustrating the oldest extant text of al-Ṣūfī (Oxford, Bodleian MS Marsh 144), both no. 30 of Centaurus and no. 11 of Lupus are eliminated from the drawing. See Wellesz [1959], fig. 17 and [1965], fig. 21.

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Makers

Each maker's name is followed by the globe numbers of the instruments that are credited to him. Globe numbers are separated from citations by colons. The primary citation for the globe is given in italics, and is followed by citations of the inscription. Secondary citations are separated from the primary ones by a semicolon. Alphabetization follows the English alphabet, and ignores the characters *ʿayn* and *hamza* and the article *al.*

Patrons and Proprietors

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